Optical Absorption Edge in γ-InSe (Excitons and Phonons)

Optical Absorption Edge in γ-InSe

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Among III - VI layered compound semiconductors, GaSe is a material which has been studied most extensively. Although InSe has the similar characteristics to the crystal structure and the optical properties of GaSe, it has been studied less thoroughly. It is known on the crystal structure of InSe that there are three different types of stacking of the layer; they are β-, ε- and γ-modification which belongs to the point group of D_{6h}, D_{3h} and C_{3v}, respectively.[1] But variation of the optical absorption spectra by different stacking sequences are not well investigated.

InSe has indirect gap of about 1.2 eV and direct gap of about 1.3 eV at room temperature. There are interesting features due to the small energy difference between direct and indirect band gap. The investigation of band structure of InSe has received considerable attention. In the present note, two-dimensional exciton characteristics are reported for γ-InSe single crystals.

Single crystals of InSe were grown from a stoichiometric melt by a Bridgeman method, where a cooling rate was set at 3 °c/h. Most part of the ingot is a good single crystal excluding the both ends, that parts are the first and the last to cool in the procedures. Crystallographic c-axis of the single crystal is almost normal to the temperature gradient of the furnace. Laue photograph of InSe taken with the X-ray beam parallel to the c-axis is shown in Fig.1. The results of Laue and rotating-crystal method show that InSe single crystals grown by the above method belong to the rhombohedral lattice, γ-modification, with the lattice parameters of equivalent hexagonal unit cell dimensions $a=3.99\pm0.01$ and $c=24.940\pm0.005$ A at room temperature.

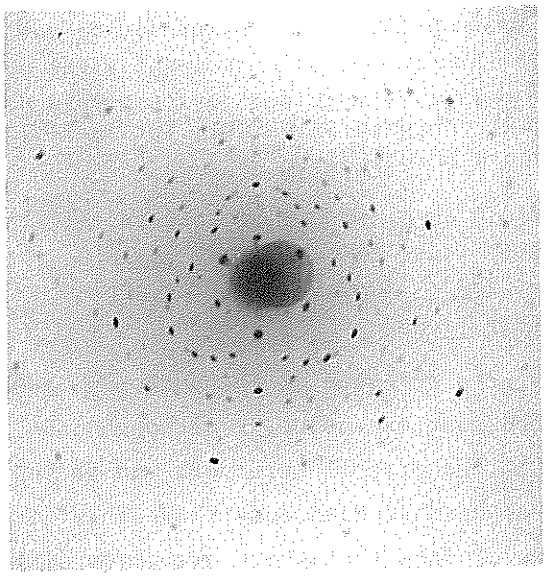
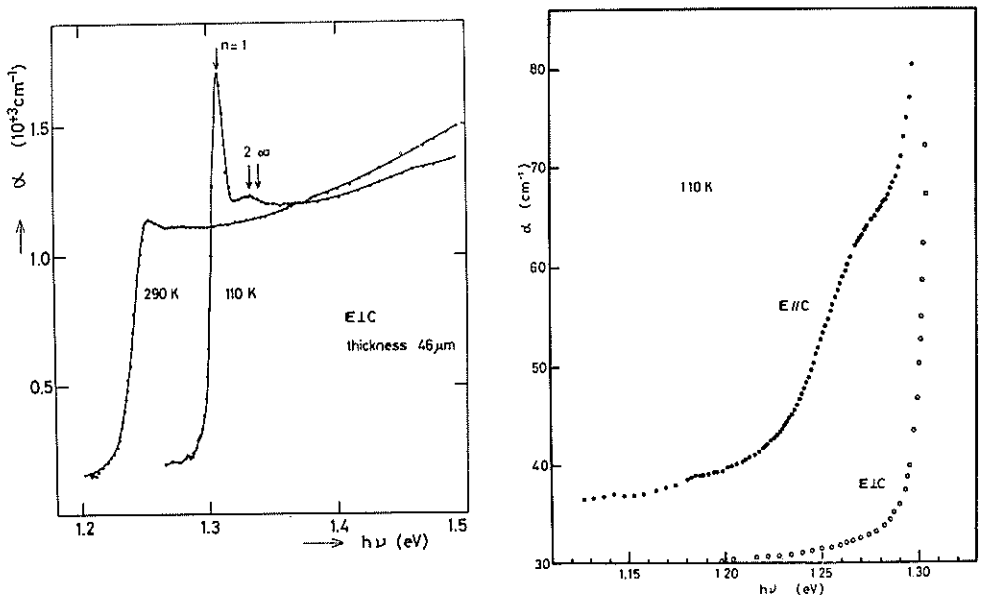


Fig.1 Laue photograph of InSe single crystal.

Diffraction peaks on the diffractometer chart were too dispersive to determine the stacking sequence by the X-ray powder method. Samples which belong to other stacking sequences, such as β- or ε-modification, are not obtained.

Since the single crystals are very easily cleft by adhesive tape, the samples with desirable thickness and optically flat surface which is perpendicular to the c-axis are obtained without any difficulities. These samples were prepared for the optical absorption measurements of light beam which was incident perpendicular to the layer ($E \perp c$; **E** is the electric field vector of light). For the measurements of light beam which was incident parallel to the layer (**E**//c), samples were cut and polished carefully to avoid surface contamination. The optical measurements were carried out in the temperature ranges from liquid nitrogen to room temperature.

Experimentally determined absorption coefficients of γ-InSe for $E \perp c$ near the absorption edge are shown in Fig.2(a), where the thickness of the sample was 46 μm. Multiple reflection effect was taken into consideration. The absorption spectra are well interpreted in terms of the transition where a three-dimensional direct exciton is participating. Direct energy gap E_g^d is 1.28 and 1.34 eV at room



(a) (b)

Fig.2.Absorption coefficient of γ-InSe as a function of incident photon energy. The thickness of the sample was (a) 46 μm and (b) 1.0 mm.

temperature and at 110 K, respectively. Exciton binding energy is about 30 meV, and this value agrees with that reported by Andriyashik et al.[2] rather than that by Camassel et al..[3] Incident photon energy dependence of absorption coefficients in $h\nu > E_g^d$ shows that the transition is direct forbidden for $E \perp c$. The value of E_g^d calculated from the absorption coefficient as a function of photon energy is well agreed with the value deduced from the exciton absorption.

Fig.2(b) shows absorption coefficients of γ-InSe at 110 K for two different polarization of light. Plateau like behavior of the absorption spectrum for E//c indicates the characteristics of two-dimensional indirect exciton as in the case for β-GaSe.[4] The abrupt decrease of absorption coefficients for $E \perp c$ shows that the indirect transition is forbidden for $E \perp c$, whereas is allowed for E//c. Further discussions concerning these spectra are to be published later.

Bakumenko et al.[5] reported similar selection rules for the indirect transition for β-InSe. Recently, Tatsuyama et al.[6] reported that indirect gap transition between Γ and M point in the Brillouin zone in γ-GaSe are allowed transition for both $\mathbf{E}//c$ and $\mathbf{E}\perp c$. These situations in the selection rules are not applicable to InSe.

It is concluded from the above investigations that the absorption edge spectrum of γ-InSe exhibits a similar behavior to that of β-GaSe. More detailed studies are necessary to make clear a influence of the stacking sequence on the optical properties.

References

1) S.Jandl and C.Carlone: Solid State Commun. 25(1978)5.
2) M.V.Andriyashik, M.Yu.Sakhnovskii, V.B.Timofeev and A.S.Yakimova: phys. stat. sol. 28(1968)277.
3) J.Camassel, P.Merle and H.Mathieu: Phys. Rev. B17(1978)4718.
4) H.Kamimura, K.Nakao and Y.Nishina: Phys. Rev. Letters 22(1969)1379.
5) V.L.Bakumenko, Z.D.Kovalyuk, L.N.Kurbatov and V.F.Chishko: Sov. Phys. Semicond. 10(1976)621.
6) C.Tatsuyama and S.Ichimura: J. Phys. Soc. Japan 44(1978)575.