Study on energy of valence-band splitting from photocurrent spectrum of photoconductive $CdGa_2Se_4$ thin films

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Abstract : The photoconductive $CdGa_2Se_4$ layer was grown through the hot wall epitaxy method. From the photocurrent (PC) measurements, the three peaks in the PC spectra were associated with the band-to-band transitions. The PC intensities were observed to decrease with decreasing temperature. The valence-band splitting on $CdGa_2Se_4$ was also observed by means of the PC spectroscopy. The crystal field splitting and the spin orbit splitting turned out to be 0.1604 and 0.4179 eV at 10 K, respectively.

Key Words : $CdGa_2Se_4$ layer, PC spectroscopy, hot wall epitaxy, valence-band splitting

1.Introduction

Cadmium gallium selenide ($CdGa_2Se_4$) is an attractive material because of its applicability to electro-optical devices [1].

In this study, photoconductive $CdGa_2Se_4$ layers were grown by the hot wall epitaxy (HWE) method. The temperature dependence of the band-gap energy was observed through the PC spectroscopic measurements. Thus, the valence-band splitting for electronic transitions restricted by a selection rule is also discussed.

2. Results and discussion

Figure 1 shows the PC spectra of the photoconductive $CdGa_2Se_4$ layer at the temperatures ranging from 10 to 293 K. As shown in Fig. 1, the PC spectrum shows a steep slope at the short wavelength region below the PC apex. This suggests that the electrons and holes generated by the incident light disappear as a result of recombination . The PC spectra with three peaks were observed at each temperature. These peak positions at 293 K were located at 487.3 (2.5443 eV), 470.4 (2.6357 eV), and 409.1 nm (3.0307 eV). The information suggests that these PC peaks are the intrinsic transition caused by the band-to-band transition [12]. Thus, the peak at 2.5443 eV, A peak, is ascribed to the electronic transition from the $\Gamma_6(\Gamma_7)$(A) valence band to the $\Gamma_5(\Gamma_8)$ conduction band. The peak at 2.6357 eV, B peak, is associated with the electronic transition from the $\Gamma_5(\Gamma_8)$(B) valence band to the $\Gamma_5(\Gamma_8)$ conduction band, and the peak at 3.0307 eV, C peak, is ascribed to the electronic transition from the $\Gamma_6(\Gamma_7)$(C) valence band to the $\Gamma_5(\Gamma_8)$ conduction band. While decreasing the measurement temperature, three peaks were continuously observed until the lowest temperature. At 10 K, the three peaks at 469.8 (2.6391 eV), 454.0 (2.7310 eV), and 396.7 nm (3.1254 eV) correspond to the peaks A, B, and C, respectively.

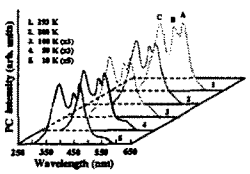

Fig. 1. A schematic diagram of the photoconductive cell prepared to measure the PC spectra

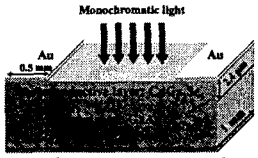

Fig. 2. PC spectra of the photoconductive $CdGa_2Se_4$ layer at the temperatures ranging from 10 to 293 K

3. Conclusion

The photoconductive $CdGa_2Se_4$ layer, which has the carrier density of 8.27×10^{17} cm^{-3} and the Hall mobility of 3.45×10^2 cm^2/V s at 293 K, was grown by using the HWE method. From the PC measurements, three peaks of A, B, and C were observed, indicating the intrinsic transitions from the valence-band states of $\Gamma_6(\Gamma_7)$(A), $\Gamma_5(\Gamma_8)$(B), and $\Gamma_6(\Gamma_7)$(C) to the conduction band state of $\Gamma_5(\Gamma_8)$. The intensities of the PC spectra decreased with decreasing temperature. The valence-band splitting on $CdGa_2Se_4$ was also observed using PC measurement. The Δ_{cr} and Δ_{so} were 0.1604 and 0.4179 eV at 10 K, respectively. By conducting the PC and absorption experiments, the band-gap energy on $CdGa_2Se_4$ was extracted out. Thus, the temperature dependence of the band-gap energy was described by $E_g(T) = E_g(0) - (7.721 \times 10^{-4})T^2/(392 + T)$. The $E_g(0)$ was estimated to be 2.6414, 2.7318, and 3.1262 eV at the valence-band states of $\Gamma_6(\Gamma_7)$(A), $\Gamma_5(\Gamma_8)$(B), and $\Gamma_6(\Gamma_7)$(C), respectively. Furthermore, the band-gap energy of $CdGa_2Se_4$ at room temperature was 2.5446 eV.

References

1. Madelung O (1996) Numerical semiconductors-basic data, 2nd edn. Springer, Berlin
2. Abdullaev GB, Agaev VG, Antonov VB, Nani RKh, Salaev EYu (1972) Sov Phys Semicond 6:1492
3. Levine CG, Bethea HM, Kasper HM (1974) IEEE J Quantum Electron. 10:904