

Absorption Coefficient Measurements of MgZnCdSe II-VI Compounds on InP Substrates and Quantum Confined Stark Effect in ZnCdSe/MgZnCdSe Multiple Quantum Wells

Hiroshi Hattori, Ichirou Nomura, Hiroyuki Shinbo, Takeshi Nagano,
Masaru Haraguchi, Toshihiro Morita, Akihiko Kikuchi and Katsumi Kishino

Department of Electrical and Electronics Engineering, Sophia University, 7-1 Kioi-cho, Chiyoda-ku, Tokyo 102, Japan
Tel: +81-3-3238-3323, Fax: +81-3-3238-3321, E-mail: kishino@katsumi.ee.sophia.ac.jp

1. Introduction

MgZnCdSe II-VI compound semiconductors grown on InP substrates are very attractive materials for wide-range visible optical devices because the bandgap energy can be changed from 2.1 to 3.6 eV by only changing Mg composition with keeping a lattice matching condition. Although the basic crystal growth and characterization of MgZnCdSe have been reported [1-5], material properties for device fabrications have not been clarified sufficiently. Especially, fabrication technologies such as chemical etching have scarcely been investigated.

In this study, it was found that InP substrates of MgZnCdSe samples were selectively removed by chemical etching using HCl:H₃PO₄ solutions. Using the etching technology, absorption coefficients of MgZnCdSe were estimated from the optical transmission measurements at room temperature. From the absorption coefficients, bandgap energies of MgZnCdSe were obtained as a function of Mg composition. Furthermore, absorption coefficient changes due to the quantum confined stark effect (QCSE) by applying electric field to ZnCdSe/MgZnCdSe multiple quantum wells (MQWs) were observed for the first time.

2. Absorption Coefficient Measurements

Mg_x(Zn_yCd_{1-y})_{1-x}Se samples were grown by the molecular beam epitaxy (MBE) on (100) InP substrates. After thermal cleaning of InP substrates at 480 °C in the growth chamber, MgZnCdSe layers were grown at 280 °C. Here, Zn composition (y) was fixed to be 0.48 for lattice matching, and MgZnCdSe layers with various Mg composition (x) were grown. The detail growth condition and the crystal properties are described elsewhere [1,2].

First of all, we investigated selective removing of InP substrates of the samples by chemical etching at room temperature for optical transmission measurements. In this study, we found HCl:H₃PO₄ solutions could be used for selective chemical etching of InP substrate. Using the solutions, InP substrates were uniformly etched, and the etching rate increased with increasing HCl concentration. For the HCl:H₃PO₄ (1:4), the etching rate was 0.51 μm/min. On the other hand, after 1-hour etching by the (1:4) solution, no etching and no surface degradations of ZnCdSe was observed. Therefore, the ZnCdSe can be used as a etching stopping layer for the (1:4) solution, for removing InP substrates. However, MgZnCdSe were not uniformly etched,

and the surface was degraded by the etching beyond a certain time. The surface degradation was probably caused from crystal defects. The etching time for producing the degradation, shortened with increasing the HCl concentration in the solution and the Mg composition in MgZnCdSe.

After removing InP substrates by the etching, optical transmission spectra of ZnCdSe and MgZnCdSe samples were measured at room temperature using a halogen light source and a monochromator. Monochromatic light was normally irradiated to the sample, and the transmission light was measured by a Si detector. Reflectance spectra of the same samples were also measured with normal incident light, and absorption coefficients were estimated from the transmission and the reflectance values. The experimental absorption coefficient spectrum of ZnCdSe is shown in Fig. 1 by open squares. From the absorption coefficient spectrum, the bandgap energy of ZnCdSe was estimated by fitting the theoretical absorption coefficient curve to the experimental one near the absorption edge. A solid line in Fig.1 indicates the theoretical absorption coefficient spectrum of ZnCdSe. From the comparison of theory and experiment, the bandgap energy (E_g) of ZnCdSe at room temperature was estimated to be 2.04 eV. Absorption coefficients and E_g of MgZnCdSe with Mg composition of 0.1 and

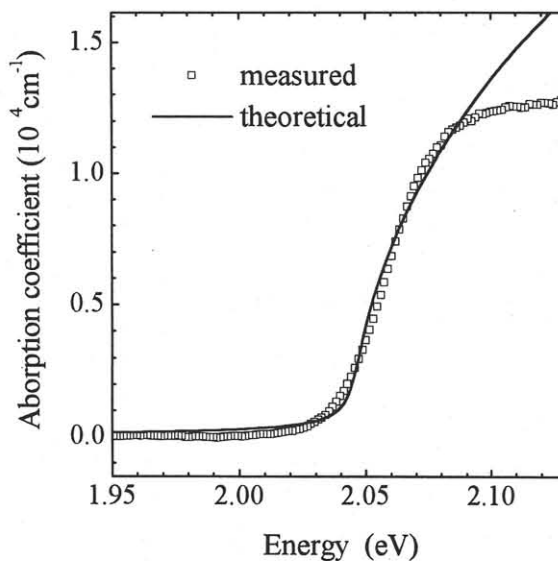


Fig. 1 Experimental (open squares) and theoretical (a solid line) absorption coefficient spectra of ZnCdSe.

0.2 were also estimated in the same way, and the bandgap energy dependency on Mg composition (x) at room temperature was obtained by the least square fitting as follows.

$$E_g=2.05+1.77x. \tag{1}$$

3. Absorption Coefficient Changes by QCSE

ZnCdSe/MgZnCdSe MQW samples were prepared on S-doped n-type (100) InP substrates. Figure 2 shows a schematic diagram of the MQW sample which consisted of a 0.5μm-thick Cl-doped n-type MgZnCdSe layer, a 50-nm undoped MgZnCdSe layer and a 25-pairs ZnCdSe(5nm)/MgZnCdSe(5nm) MQW structure. Here, Mg composition (x) in MgZnCdSe layer was 0.27. For applying electric field to the samples, the semi-transparent Pt circle and Au ring Schottky contact electrodes were made on the top surface. Back-side optical windows in the InP substrate were formed by the selective etching using a HCl:H₃PO₄ (1:4) solution. Ohmic contacts in the substrate side were made using Ga-In alloy.

Absorption coefficients of the MQW samples were measured at room temperature in the same way described in Sec. 2 with applying voltage to the samples. Figure 3 shows the spectra of the absorption coefficient change between zero bias and applied voltages from -1.0 to -7.5 V. The voltages corresponded to electric field from 2.5×10⁴ to 1.9×10⁵ V/cm. From this figure, absorption coefficient changes due to the QCSE were observed near the excitonic transition gap. The absorption coefficient changes which were smaller than the reported values for ZnSe/ZnCdSe MQW devices grown on GaAs substrates [6] may be improved by optimizing the growth condition and the sample structure.

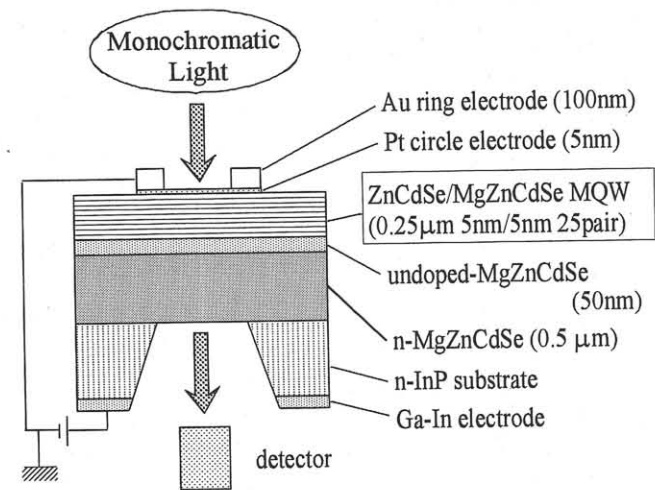


Fig. 2 A schematic diagram of the ZnCdSe/MgZnCdSe MQW sample.

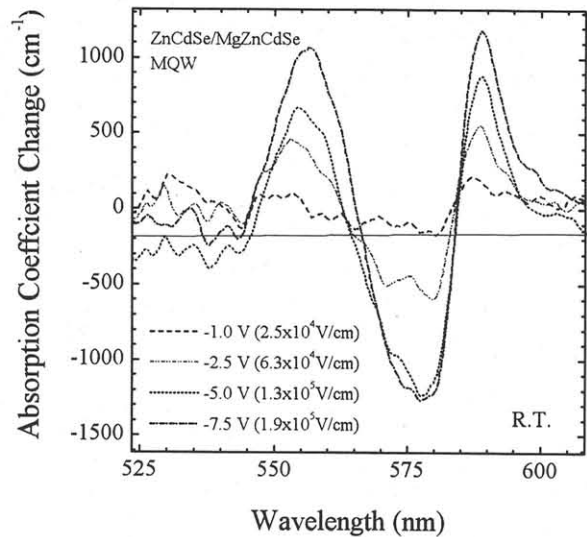


Fig. 3 Absorption coefficient change spectra of the ZnCdSe/MgZnCdSe MQW sample.

4. Summary

It was found that InP substrates of MgZnCdSe samples were preferentially removed using HCl:H₃PO₄ chemical-etching solutions. Using the technology, the optical transmission measurements of MgZnCdSe were performed to estimate the absorption coefficients at room temperature. From these, bandgap energies of MgZnCdSe were obtained as a function of Mg composition. The QCSE in ZnCdSe /MgZnCdSe MQWs was investigated, and the absorption coefficient changes due to applying electric field were observed.

Acknowledgements

This work was partly supported by a scientific research grant-in-aid from the Ministry of Education, and Science, Sports and Culture of Japan, and Kanagawa Academy of Science and Technology Research Grants.

References

- [1] T. Morita, A. Kikuchi, I. Nomura and K. Kishino: J. Electron. Mater., Vol.25, No.3 (1996) 425-429.
- [2] I. Nomura, T. Morita, A. Kikuchi and K. Kishino: J. Cryst. Growth, Vol.159 (1996) 11-15.
- [3] N. Dai, A. Cavus, R. Dzakupasu, M. C. Tamargo, F. Semendy, N. Bambha, D. M. Hwang and C. Y. Chen: Appl. Phys. Lett., 66 (1995) 2742
- [4] K. Naniwae, H. Iwata, N. Kuroda, K. Yashiki, M. Kuramoto and T. Suzuki: J. Cryst. Growth, Vol.159 (1996) 36
- [5] M. C. Tamargo, A. Cavus, L. Zeng, N. Dai, N. Bambha, A. Gray, F. Semendy, W. Krystek and F. H. Pollak, J. Electron. Mater., Vol.25 (1996) 259
- [6] B. C. Cavenett, P. J. Thompson, G. D. Brownlie, S. Y. Wang and K. A. Prior: Proceedings of Int. Symp. on Blue Laser and Light Emitting Diodes, chiba, (1996) Th-14 p.277