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Electrooptic Characterization of Five-Layer Asymmetric Coupled Quantum Well

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1. Introduction

Ultrafast modulations with a bandwidth of over 100 GHz require a modulation voltage of less than 1 V and a short metal electrode for decreasing the microwave loss. The Mach-Zehnder modulator with a multiple quantum well (MQW) waveguide, which is based on phase modulation, is an important candidate because of its frequency-chirp-free characteristics. For such modulators based on phase modulation, a large electrorefractive index change Δn with a small absorption loss is required. In a rectangular quantum well (RQW), however, the region of the large Δn is usually at or very close to the absorption edge of the electron l-heavy hole 1 (e1-hh1) transition. Hence, in that region Δn cannot be used because of too large an absorption loss. In the longer operation wavelength region, Δn of the RQW decreases steeply [1] because the positive and negative absorption coefficient changes cancel each other out in the Kramers-Kronig relation [2][3].

2. Feature of FACQW

The group with one of the present authors previously proposed a five-layer asymmetric coupled quantum well (FACQW) which is a new potential-tailored quantum well for ultrafast and low-voltage optical modulators and switches [4].The FACQW can obtain an almost linear, very large electrorefractive index change ($\Delta n / \Delta F \sim$ 0.0002 cm/kV) in the transparency wavelength region where there is little absorption. The Δn of the FACQW is larger by over one order of magnitude than that of conventional RQWs. If the FACQW is applied to optical modulators and switches, ultrafast and low-voltage operation can be realized over a very wide wavelength range. It has been demonstrated that a Mach-Zehnder interferometer traveling-wave-type optical modulator with FACQW structures can achieve a smaller driving voltage than one with RQWs and the modulation bandwidth of over 50 GHz [5].

3. Experiments

Fig.1 shows reflection high energy electron diffraction (RHEED) specular beam intensity oscillation during the growth of the FACQW by using MBE method with a computer-controlled accurate shutter movement. It is clear that the FACQW was fabricated with an atomic layer precision. An FACQW sample with 5 periods was grown on n-doped GaAs (100) substrate with MBE. Fig.2 shows that the sample is prepared with an Au Schottky electrode for applying an electric field and collecting photocurrent while an In ohmic contact is fabricated on the back of sample. The absorption current spectra were measured at normal incidence of light to cleaved side facet. Fig.3 (a) shows the measured absorption current spectra. The measured absorption edge does not move toward the longer wavelength. While electric field is applied, it turns out that peaks do not decline. This is in good agreement with the theory [4]. As a comparison, Fig.3 (b) shows the measured photocurrent absorption spectra of an RQW with 25 periods. Absorption peak at the absorption edge shifts to the long wavelength side with increased electric field, and attenuation of the peak is observed. It is clear from both figures that there are different absorption changes versus bias characteristics for the two structures.

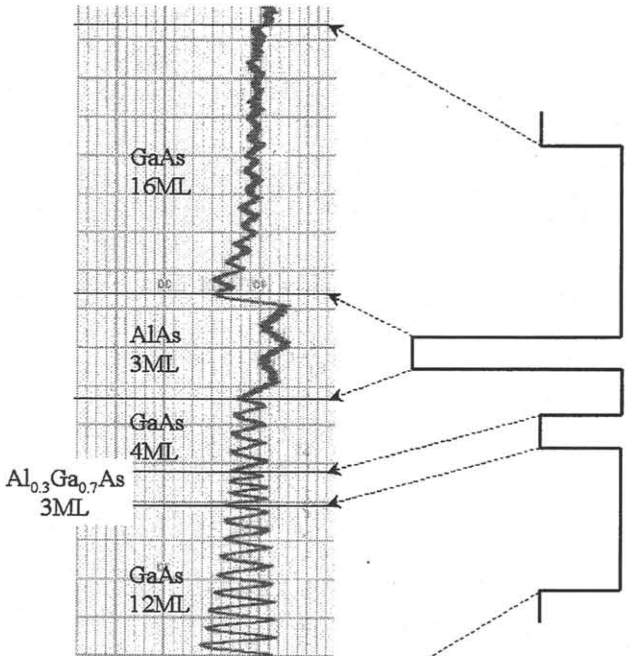

Fig.1 RHEED specular beam intensity oscillation during the growth of the FACQW with MBE method grown at 600℃

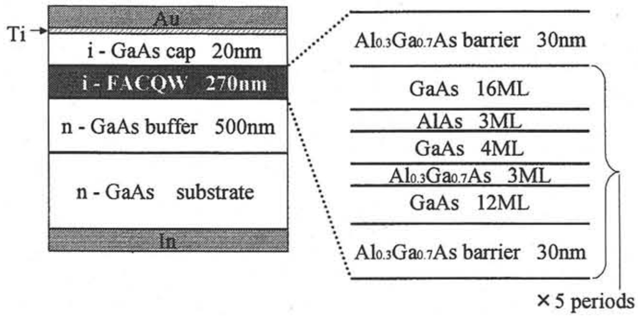

Fig.2 Sample structure for measurement of current absorption spectra.

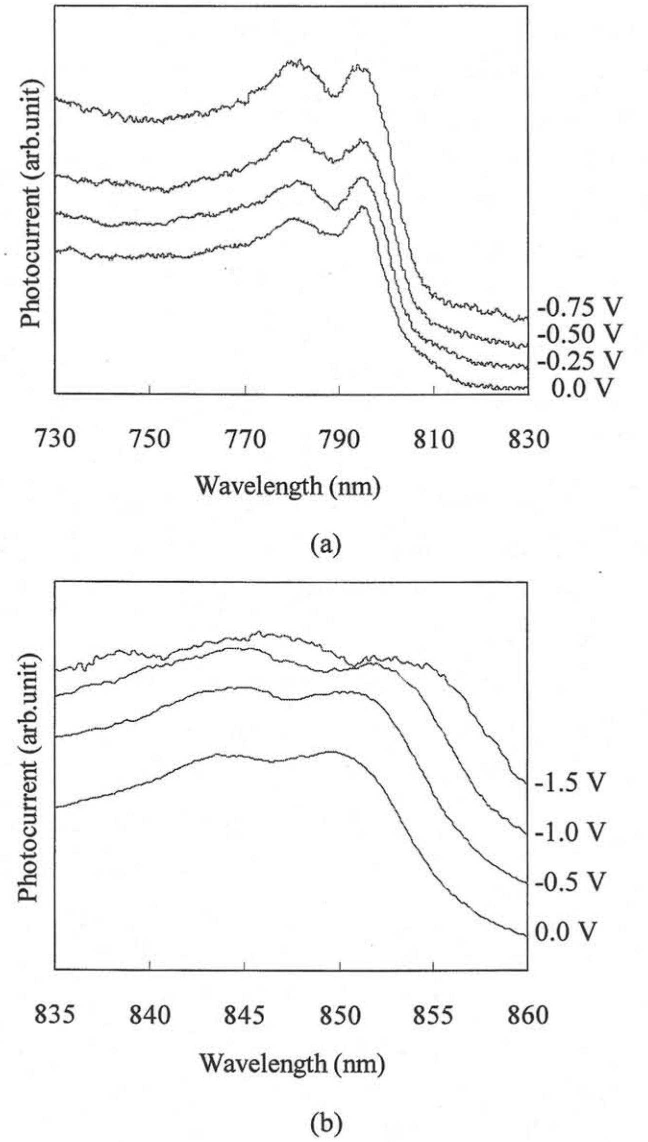

Fig.3 Measured photocurrent absorption spectra of the FACQW (a) and an RQW (b) at room temperature.

4. Trial of the MEE method

Furthermore, in order to fabricate better FACQW, we applied the migration enhanced epitaxy (MEE) method[6]. The MEE method has the feature that a steep and flat heterointerface canbe realized at a growth temperature lower than the conventional MBE method. Therefore, we tried to optimize the growth conditions of the GaAs/AlGaAs quantum well with the MEE method in order to fabricate better samples of FACQW. In the growth of AlGaAs with MEE method, the materials supply sequence is important because of intermixing of Al atoms [7]. We tried several materials supply sequences. Among then, the materials supply sequence as shown in Fig.4 has been found to be the best in view of photoluminescence spectra of GaAs/AlGaAs RQW samples compared with those of samples grown by conventional MBE.

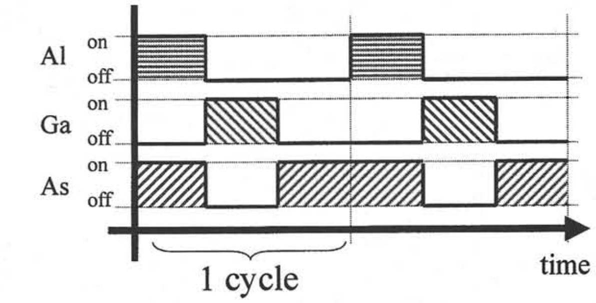

Fig.4 The best materials supply sequence for growing AlGaAs.

5. Conclusions

We fabricated by MBE method a FACQW sample with high precision, which can exhibit strong absorption coefficient enhancement without redshift of the absorption edge under a negative bias field. By proper combination of MBE and MEE method, a better sample of FACQW will be fabricated at lower growth temperature than that for MBE method only. The structure is expected to produce a large refractive index change with small absorption loss.

References

[1] J. E. Zucker and T. L. Hendrickson, Appl. Phys. Lett. **52** (1988) 932.

[2] N. Susa, J. Appl. Phys. **73** (1993) 932.

[3] N. Susa, J. Appl. Phys. **73** (1993) 8463.

[4] H. Feng, J. P. Pang, M. Sugiyama, K. Tada, and Y. Nakano, IEEE J. Quantum Electron. **34** (1998) 1197.

[5] J. P. Pang, K. Tada, Y. Nakano and H. Feng, *Tech. Dig. Third Optoelectronics and Communications Conf. (OECC '98),* Makuhari, 1998, 454.

[6] Y. Horikoshi, M. kawashima, and H. Yamaguchi, Jpn. J. Appl. Phys., **25**, (1986) 868.

[7]Y. Morishita, S. Goto, Y. Nomura, T. Isu, and Y. Katayama, Jpn. J. Appl. Phys., **32**, (1993) 222.