Unusual Magneto-infrared Modes in CdMnTe/CdMgTe Quantum Well Structures

L.C. Tung (NHMFL), G. Karczewski (Polish Academy of Science), and Y.J. Wang (NHMFL)

Introduction

CdMnTe quantum well structures have been a focus of interests for a few decades because of its potential application in spintronics and the abundance of novel physical phenomena found in this system [1-3]. The strong s-d exchange interaction between conduction electrons and Mn spins has led to a giant and tunable g factor [2], which can give rise a Zeeman splitting as large as the separation of Landau level [3]. Furthermore, CdTe based-system has a Frohlich electron-phonon coupling constant,0.3, which is more than 4 times stronger than that of GaAs. All of these conditions may lead to observable phenomena resulted from the coupling between spins, orbital motions and phonon modes.

Experimental

We have carried out a systematic study on a series of modulation doped CdMnTe/CdMgTe single quantum well (QW) samples with a range of electron concentrations (up to $5x10^{11}cm^{-2}$) and Mn compositions (0-16%) in the field up to 35 T. In addition to cyclotron resonance (CR), several infrared (IR) modes have been observed at liquid helium temperature. In the absence of the magnetic field, they are positioned at 123 (B1), 157 (M1) and 172 (M2) cm^{-1}, respectively.

Results and Discussion

When the sample is in the dark, the only observable feature is the CR, and all three modes B1, M1 and M2 can only be activated by visible light, and once they are activated, there is no sign of degradation over 24 hours. The intensity of these modes vanishes at temperatures higher than 50 K, suggesting that they are resulted from local excitations. To understand the nature of these modes, we have tilted the samples in magnetic field to study their angular dependence. When the tilting angle is increased, a systematic change has been observed. It is very clear that B1's energy shifts to lower energy as the sample is tilted. B1's energy changes slowly with B, but its intensity increases rapidly with increasing B. The former indicates that it is possibly a phonon-like mode, while the later indicates that this mode is magnetic. This behavior seems to resemble the behavior of the spin-dependent phonon modes [4,5]. M2's behavior is the most interesting. In the absence of magnetic field, M2's energy is positioned at 172 cm^{-1}, which is in close proximity of CdTe LO phonon frequency. With increase of magnetic field, the transition energy monotonically increases with the field with the slope about 2 cm^{-1} /T, and the linewidth of the absorption becomes broader, and develops at B > 10 T into at least two well-resolved features, M2a with lower energy and stronger absorption and M2b with higher energy and weaker absorption. So the M2 actually is degenerate at zero field, and the degeneracy is removed at high fields due to the difference in their magnetic field dependence. When the sample is tilted inside the magnet, the energy dependence of both M2a and M2b remains the same, as if these two modes are bulk and/or isotropic transitions. But their relative absorption strength shows entirely different behavior as shown in the Fig. 2. The M2b's intensity increases with tilting angle at the expense of M2a. Our Voigt geometry measurement shows that M2 is a light orientation dependent mode, and it has an in-plane (M2b) sensitive term and an out-of-plane sensitive (M2a) term. M2b mainly interacts with the grazing light, while M2a is more sensitive to the out-of-plane light. Based upon this model one can then understand why M2b's intensity increases with increasing angle while M2a nearly vanishes at high angle.

Conclusions

Although the behavior of B1, M1, and M2 has been well studied, the origins of these modes are still not confirmed, mainly due to the very unusual behavior of these modes. Further understanding is still needed.

References

[1] Tatarrenko, T. et al, Opto-Electronics Reviews **11**, 133 (2003).
[2] Wojtowicz, T. et al, J. Crystal Growth **214-215**, 378 (2000).
[3] Semiconductor and Semimetals, edited by Furdyna, J.K., and Kossut, J. (Academic Press, London, 1988).
[4] Baltensperger, W. et al, J. Appl. Phys. **41,** 1052 (1970).
[5] Allen, S.J., et al, Phys. Rev. Lett. **21**, 1807 (1968).