Cyclotron Resonance in InGaAs/InAlAs two-dimensional Rashba systems

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Large zero-field spin splitting has been studied intensively in various semiconductors for realizing novel spintronic applications, such as the spin FET. Among narrow gap semiconductors, an InGaAs system, which has a larger spin-orbit interaction, is one of good candidates for studying the structure induced spin splitting, namely, the Rashba effect. The zero-field spin splitting energy was estimated mostly through the Shubnikov-de Haas oscillation (SdH) measurements. On the other hand, the optical method, such as cyclotron resonance (CR), is also an appropriate method, in particular, to obtain the magnetic field dependence of the spin splitting energy. Because the Zeeman splitting becomes dominant at higher magnetic fields in comparison with the Rashba spin splitting, the CR measurement at a wide range of the frequency range is quite essential to determine the Rashba spin-orbit interaction and the effective g-factor quantitatively.

In this study, we measured the CR in high In-content InGaAs/InAlAs inverted heterostructures at the wide range of a terahertz region by using a millimeter vector network analyzer (MVNA) and a Fourier transform infrared spectrometer. The samples were grown by the molecular beam epitaxy method on semi-insulating GaAs substrates. The SdH oscillation and the quantum Hall plateau are observed at integer filling factor by the high field transport measurements. The carrier concentration and the mobility are obtained as $n \sim 10^{12} cm^{-2}$ and $\mu = 20 m^2/Vs$, respectively.

A single CR peak is observed at the wide frequency region, and the electron effective mass is obtained as $m^* = 0.04 m_0$ from the magnetic field dependence of the resonant frequency. This value is coincident with the previous work in the THz cyclotron resonance with using a FIR laser. In addition, we also found that an additional resonant peak was appeared only at some frequency region. The anomalous two resonant peaks are confirmed by the R-θ analysis of the CR data, and this is probably due to the anti-crossing of different spin levels that are coupled through the large spin-orbit interaction of the InGaAs systems.