Chapter 5

Conclusions

In this thesis, MOCVD epitaxy theory was viewed and was used to grow the InGaP/GaAs heterostructures by using fast gas switching method. A novel Cu/Mo/Ge/Pd ohmic contact was developed for the fabrication of the MOCVD grown HBT structure. The refractory metal molybdenum was used as a diffusion barrier between Cu and underlying materials. The diffusion behavior of Cu/Ta/GaAs multilayers after thermal annealing was also investigated. Tantalum, as a barrier, was found to be very stable up to 500 °C without Cu diffusion into GaAs. The primary results obtained in this thesis are concluded below:

(1) By judging from the DCXRD, PL, and SEM analysis data, sharp interfaces can be achieved in the InGaP/GaAs heterointerfaces by adjusting group V switching time. Under a fixed InGaP composition, a high band gap of 1.93 eV can be obtained at 730℃, showing a more disorder characteristic. However, a low band gap of 1.83 eV corresponding to an atomically ordered distribution was grown at 630℃ as judged by the PL measurement. Raman spectra analysis also shows that the InGaP grown at 730℃ exhibits a more disordered characteristic and demonstrated a transverse-optical (TO) phonon mode which is forbidden for the ordered InGaP grown at 620℃.

(2) A novel Cu/Mo/Ge/Pd ohmic contact was characterized and applied to n^+-GaAs for HBT applications. The Cu/Mo/Ge/Pd ohmic contact structure reached the lowest contact resistance, which was measured to be $2.8\times10^{-7}\ \Omega\ \mathrm{cm}^2$, when annealed at 350℃. However, the contact structures deteriorated owing to the interfacial reactions between Cu and the underneath films when annealed at 400℃. The sheet resistance,

XRD, AES, and TEM analysis data also indicate that Mo is a reliable diffusion barrier for Cu-based ohmic contacts to n^+-GaAs even after up to 350℃ annealing. The InGaP/GaAs HBTs with the Cu/Mo/Ge/Pd ohmic contact were also fabricated and studied. From the device characterizations, the HBTs fabricated using the traditional n-type ohmic metal (Au/Ge/Ni/Au) and the HBTs fabricated using the proposed Cu/Mo/Ge/Pd n-type ohmic metal showed comparable electrical characteristics. The devices with the Cu/Mo/Ge/Pd ohmic contacts were thermally annealed at 250℃ for 24 h to study the thermal stability and showed no obvious electrical degradation after the thermal test. Under a high current density of 120 kA/cm^2 at a V_{CE} of 1.5 V for 24 h, the HBTs with the novel Cu/Mo/Ge/Pd ohmic contacts show negligible change in electrical characteristics. The experimental results in this study suggest that Cu/Mo/Ge/Pd is an effective copper-based ohmic contact structure and can be used for the future copper metallization of the GaAs based electronic devices.

(3) The thermal stability and failure mechanism of Cu/Ta/GaAs were studied in this thesis. It was shown that copper metallization on GaAs with Ta as the diffusion barrier layer is stable after annealing up to 500 °C. However, after annealing at 550 °C, the interfacial reaction of Ta with GaAs substrate occurred, the reaction of As with Ta resulted in the formation of $TaAs_2$ in the Ta/Cu interface, and the diffusion of Ga through Ta into the Cu layer formed the Cu_3Ga phase at the Cu/Ta interface. After annealing at 600 °C, the multilayer structure was destroyed as a result of the strong reaction of Ta with As to form TaAs and the reaction of Cu with Ga to form Cu_3Ga. Ta fails to act as an effective diffusion barrier between Cu and GaAs at this

temperature. .