

The Study of Copper Metallization for InGaP/GaAs HBTs Grown by MOCVD

Student: Chun-Wei Chang

Advisor: Dr. Edward Yi Chang

Department of Materials Science and Engineering
National Chiao Tung University

Abstract

In this thesis, copper metallization of InGaP/GaAs heterojunction bipolar transistor grown by metal-organic chemical vapor deposition (MOCVD) and the diffusion mechanism and the thermal stability for the Cu/Ta/GaAs structure with Ta as the barrier are studied.

First, the characterization and control of InGaP/GaAs heterostructure grown by MOCVD for HBT application were studied. Interface abruptness and the ordering effect of InGaP were characterized by photoluminescence (PL), Double crystal X-ray diffraction (DCXRD), scanning electron microscopy (SEM), Raman scattering spectra. A very smooth interface can be obtained by controlling the switching time of III and V precursors and V/III ratio. The PL data and the Raman spectra clearly evidenced the ordering phenomenon of the InGaP layer. A high band gap of 1.93 eV showing a more disorder characteristic was obtained when the film was grown at 730°C and a low band gap of 1.83 eV corresponding to an atomically ordered distribution was obtained when grown at 620°C.

Second, the Cu-metallized InGaP/GaAs HBT, with lattice-matched disordered InGaP structure was manufactured, this device exhibited comparable device

performances with Au-metallized HBT. In this study, a novel Cu/Mo/Ge/Pd ohmic contact was characterized and applied to the n⁺-GaAs for HBT applications. The Cu/Mo/Ge/Pd ohmic contact structure reached the lowest contact resistance and was measured to be $2.8 \times 10^{-7} \Omega \text{cm}^2$ after annealing at 350°C. However, the contact structures deteriorated owing to the interfacial reactions between Cu and the underlying layers when annealed at 400°C. The sheet resistance, XRD, AES and TEM analysis data also indicate that Mo is a reliable diffusion barrier for the Cu-based ohmic contacts to n⁺-GaAs up to 350°C annealing. The devices with the Cu/Mo/Ge/Pd ohmic contacts were also thermally annealed at 250°C for 24 hours for thermal stability study and showed no obvious electrical degradation after the thermal test. Under the high current density of 120kA/cm² at a V_{CE} of 1.5V for 24 hours, the HBTs with the novel Cu/Mo/Ge/Pd ohmic contacts show little change in electrical characteristics.

Third, the mechanism of tantalum inserting as a barrier between Cu and GaAs is investigated. A thin 30 nm tantalum layer was sputtered as a diffusion barrier to block the Ga and As diffusion into the Cu layer. Judging from the data of sheet resistance measurement, X-ray diffraction analysis, Auger electron spectroscopy and transmission electron microscopy, the Cu/Ta films on GaAs were found to be very stable up to 500 °C without Cu migration into GaAs. However, after annealing at 550 and 600°C, some extra compounds such as TaAs₂, Cu₃Ga, and TaAs formed owing to barrier deterioration and interfacial instability.