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CVD growth conditions, particularly growth temperature and partial pressures of the reactant gases, strongly affect the growth characteristics and properties of GaAs$_{0.6}$P$_{0.4}$ epitaxial layers grown on GaAs substrates. For LED's, the most important properties of the material are B/J (brightness per unit current density) and surface morphology. This paper presents the results of a systematic study of the effect of temperature and reactant gas partial pressure (at a fixed III/V ratio) on B/J, surface morphology, growth rate, impurity doping and layer composition. Growth conditions which yield the optimum properties for LED's are determined. The results are interpreted on the basis of kinetic and thermodynamic mechanisms controlling the growth process under various growth conditions. At constant temperature and constant III/V ratio, increasing the partial pressures causes the growth process to change from mass transport limited, where the growth rate increases with increasing partial pressures, to kinetically limited, where the growth rate is independent of partial pressures. Good morphology layers are obtained over a range of partial pressures around the transition from mass transport limited to kinetically limited growth. The B/J peaks at a value of partial pressure in the kinetically limited
regime at which good morphology layers are obtained. Although B/J increases with increasing growth rate in the mass transport regime, the maximum B/J occurs in the region where growth rate is independent of partial pressures so that growth rate alone is not sufficient to determine B/J. In contrast to the "parabolic" dependence of growth rate on growth temperature, caused by the transition from the mass transport regime to the kinetic regime, the relative incorporation of As, P, and Te varies with temperature in the manner predicted from thermodynamics in both regimes. This behavior is consistent with the growth rate in the kinetic regime being limited by the desorption of chlorine atoms from the growth surface, with the reaction of As, P, and Te with the Ga proceeding thermodynamically at all temperatures.

Key Words: GaAs$_{0.6}$P$_{0.4}$, vapor-phase epitaxy, light-emitting diodes.

Introduction

The preparation of GaAs and Ga(As,P) semiconductors by vapor phase epitaxy (VPE) in open-tube systems has been reported by many authors (1-6). A large portion of the published work has been directed toward the understanding of the basic nature of the epitaxial process. Shaw (6-8) studied the temperature dependence of growth rate as a function of substrate orientation and total flow rate. His studies led to the identification of mass transport (quasi-equilibrium) and kinetic regimes of the growth process. Ban (9) used the mass-spectrometer to determine the relative abundance and reactivities of the major species involved in the deposition process, so that the relative contribution of the various possible reactions governing the deposition processes were identified. Equilibrium constants of the reactions that occur during the growth process have been determined by Kirwan (10) and by others (11-13). Theoretical calculations (14-19) using these equilibrium constants, therefore, can be made to predict the trends of growth rate and epitaxial layer composition as a function growth temperature and partial pressures in the mass transport regime.