NEARLY EQUILIBRIUM GROWTH OF $\text{In}_{1-x}\text{Ga}_{x}\text{As}_{y}\text{P}_{1-y}$

$(0 < y \leq 1)$ Lattice-Matched to <100> InP

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Data for nearly-equilibrium LPE growth at 626°C of InGaAs lattice-matched to the <100> face of InP are presented and the modeling of phase equilibria in this system is discussed. Because the simple solution approximation, which is useful for modeling binary (InP) and ternary (InGaAs) growth, is found to be unsatisfactory for the quaternary, a semi-empirical model suitable for determining the phase equilibria for LPE growth of any lattice-matched composition over a wide temperature range is proposed. The model is based on a simple scaling of data for lattice-matched growth at one liquidus temperature, 626°C, to other temperatures using data for the two lattice-matching compositions, InP and InGaAs, for which the temperature dependencies can be calculated. Using this "model", melt compositions for growth with $600 \leq T \leq 660$°C are calculated and compared with experimental results. The nearly-equilibrium growth technique is fully described and empirical techniques for adjusting melt compositions to improve the degree of lattice-match are also given.

Key words: LPE, InGaAsP alloys, phase equilibria.
Introduction

The importance of the quaternary compound InGaAsP for the fabrication of diode lasers and detectors in the 1.0 to 1.6 μm wavelength range is well recognized [1,2]. Many workers growing this material have used either a two-phase solution growth technique [3] or a step-cooled growth technique [4]. Both of these techniques are non-equilibrium techniques with the added problem in the former case that the melt composition is unknown. Thus, neither of these methods lends itself to modeling by traditional phase equilibrium techniques. This makes it difficult to use a set of growth parameters found to be suitable for producing layers of given compositions at particular temperatures, to grow other compositions at the same, or at other temperatures. It may also account for the problems experienced in reproducing results at different laboratories.

A third technique is the nearly equilibrium cooling growth technique [5,6]. In this growth technique, the composition of the melt is accurately known, growth is initiated with a minimum of super- or step cooling; and a very small rate of temperature decrease is used. Consequently, the growth can be modeled with a high degree of confidence, and most importantly, once a model is available, it can be used to predict the melt composition for the growth of any lattice-matched composition in a wide range of growth temperatures.

In this paper we present phase diagram data for the growth of InGaAsP on the (100) surface of InP over the entire range of lattice-matched compositions using the nearly equilibrium growth technique [5].

With regard to phase equilibria models, it is argued that while the conventional simple solution model originally presented by Jordan et al. [7] is suitable for modelling the binary InP and ternary InGaAs, it is unsatisfactory for the quaternary InGaAsP. Consequently, a semi-empirical model suitable for determining the phase equilibria for LPE growth of any lattice-matched composition over a wide temperature range is proposed. The model is based on a simple scaling of data for lattice-matched growth at one liquidus temperature, 626°C, to other temperatures using data for the two lattice-matching compositions, InP and InGaAs, for which the temperature dependencies can be calculated.