MEASURED COMPOSITIONS AND LASER EMISSION WAVELENGTHS OF Ga\textsubscript{x}In\textsubscript{1-x}As\textsubscript{y}P\textsubscript{1-y} LPE LAYERS LATTICE-MATCHED TO InP SUBSTRATES

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The alloy compositions of Ga\textsubscript{x}In\textsubscript{1-x}As\textsubscript{y}P\textsubscript{1-y} LPE layers lattice-matched to InP substrates have been determined by electron microprobe analysis. The composition data are well represented by \( x = 0.40y + 0.067y^2 \). The emission wavelengths of lattice-matched Ga\textsubscript{x}In\textsubscript{1-x}As\textsubscript{y}P\textsubscript{1-y}/InP double-heterostructure diode lasers have been measured at 300 and 80 K. The photon energies for laser emission at 300 K are given by \( h\nu (\text{eV}) = 1.307 - 0.60y + 0.03y^2 \). The emission energies at 80 K are 57 meV higher.

Key words: Ga\textsubscript{x}In\textsubscript{1-x}As\textsubscript{y}P\textsubscript{1-y}, LPE, lattice constant, laser emission energy.

This paper reports the experimental determination of two properties of Ga\textsubscript{x}In\textsubscript{1-x}As\textsubscript{y}P\textsubscript{1-y} alloys that are important for optoelectronic applications in the near-infrared region of the spectrum: the compositions of alloy layers that are lattice-matched to InP substrates and the emission wavelengths of double-heterostructure (DH) diode lasers utilizing such layers.

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The preparation of device-quality semiconductor epitaxial layers requires that the lattice constants of the growth layers and their substrates be closely matched. Lattice matching is especially critical for the effective operation of DH diode lasers because mismatch between the active region and the adjacent barrier layers results in the formation of defects that seriously reduce efficiency and can shorten device lifetime. Since quaternary Ga$_x$In$_{1-x}$As$_y$P$_{1-y}$ alloys can be exactly lattice-matched to InP over a range of compositions that give energy gaps corresponding to any wavelength between 0.92 and 1.7 μm, these alloys are of particular interest for optoelectronic devices operating in this spectral region. Both photoemissive devices (1) and long-lived DH diode lasers operating continuously at room temperature (2, 3) have been fabricated with Ga$_x$In$_{1-x}$As$_y$P$_{1-y}$ layers grown by liquid-phase epitaxy (LPE) on InP substrates, and avalanche photodiode detectors are under development. The diode lasers are potentially important as sources for fiber optic communication systems, since they can operate in the 1.2-1.3 μm wavelength region, where fused silica fibers have their minimum absorption (4) and material dispersion (5).

In the Ga$_x$In$_{1-x}$As$_y$P$_{1-y}$ alloys, both x and y can take any value between 0 and 1, with each varying independently of the other. For those alloys having the same lattice constant as InP, however, x and y are no longer independent. To select the particular alloy composition required for Ga$_x$In$_{1-x}$As$_y$P$_{1-y}$/InP devices operating at a specific wavelength it is necessary to know both the functional relationship of x to y and the composition-wavelength relationship for the lattice-matched alloys. Although scattered data are available, no systematic experimental determination of these relationships over a wide composition range has been reported. We have now carried out such a determination.

To determine the x-y relationship for lattice-matched Ga$_x$In$_{1-x}$As$_y$P$_{1-y}$ alloys, LPE layers 2-3 μm thick were grown on (111)B- or (100)-oriented single-crystal InP substrates by a supercooling technique described previously (6), which uses a high-purity graphite slider boat. The alloy composition is a sensitive function of the composition of the growth solution, the degree to which the solution is supercooled, and the orientation (7). An InP buffer layer was grown immediately before the alloy epilayer in order to minimize imperfections due to thermal etching of the substrate during heating. The lattice constant of the alloy was found by using an x-ray diffractometer, employing Cu K$_\alpha$ radiation, to measure the angular position of the (444) or