MODULATION OF ELECTRONIC PROPERTIES IN LIQUID PHASE
EPITAXIALLY GROWN p-n-p-n GaAs MULTILAYERS

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Liquid phase epitaxy (LPE) is presented as an alternative
method to molecular beam epitaxy (MBE) for growing p-n-p-n
doped GaAs superlattices. LPE offers some advantages
compared to MBE. Simple equipment, shorter growth times
at comparable low growth temperatures, permits growing
multilayers with a broad variety of single layer thick-
ness 20 < d < 1000 nm at reasonably short growth times.

Typical doping superlattice properties are tested in
LPE multilayers, and demonstrated via some selected
results: a) The simultaneous modulation of the conduc-
tivities in the n- and p-layer systems. It depends on
the variation of the 2-dim. carrier concentrations and to
a similar extent on the change of the mobilities with the
effective channel thickness. b) The field effect tran-
sistor properties of the p-and n-doped systems are due to
the special choice of doping concentrations and film
thicknesses. c) The modulation of the effective band gap
E\text{g}\text{f} is proved by cw and time resolved photoluminescence.
Good agreement is achieved between the expected shift E\text{g}\text{f}
due to the LPE growth parameters and the observed shift
of the peak energy of the luminescence spectra.
From the point of view of crystal growth, growing p-n-p-n or n-i-p-i doping superlattices instead of compositional ones offers some advantages as confinement to one homogeneous crystal, reduction of interface problems, and nevertheless a broad variety in film thickness and/or doping variation for realizing particularly desired electronic properties.

Using a relatively well established growth technique namely the liquid phase epitaxy (LPE), Rezek and coworkers\(^2\) already have successfully grown In\(_{1-x}\)Ga\(_x\)P\(_{1-z}\)As\(_z\)/InP multilayer structures with layer thicknesses < 50 nm by using the constant-temperature LPE growth procedure in a cylindrical graphite boat.\(^3\) One of our leading motivations of this paper is to show that extremely thin multilayers can be also be grown by using a constant cooling rate LPE growth procedure in an often used, slightly modified linear sliding boat.

The second aspect is to prove that the LPE n-i-p-i structures really exhibit the very unusual electronic and optical properties which are due to a tunable band structure.\(^4,5\) For example, the effective band gap \(E_{\text{eff}}\) of bulk GaAs becomes tunable by variation \(\Delta_n = \Delta_p\) of the electron and hole concentration. Increasing carrier concentration decreases the one-dimensional space charge potential amplitude and consequently increases \(E_{\text{eff}}\). Large deviation from thermal equilibrium becomes quasi-stable. The reason is that the space charge potential causes a modulation of the conduction and valence band edges and leads to a separation of valence band maximum and conduction band minimum by half a superlattice period in real space. As a consequence, electrons and holes are spatially separated from each other leading to many orders of magnitude longer lifetimes in an excited state.