Heterointerface Optimization in InP Based Strained MQW Laser Structures Using Metalorganic Growth Technologies

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For the fabrication of high performance long wavelength lasers, epitaxial growth of high quality strained GaInAsP MQW structures is mandatory (1). Epitaxial growth of InP based laser structures has routinely been performed by metalorganic vapor phase epitaxy (MOVPE), and more recently also by metalorganic molecular beam epitaxy (MOMBE or CBE - chemical beam epitaxy) (2). In strained MQW structures at higher strain, however, the formation of wavy interfaces may occur (3) yielding deteriorated device performance. We present a deeper insight into the effect of both, growth parameters and barrier material composition, on strain induced mechanisms causing interface degradation in strained MQW structures grown by both metalorganic growth technologies.

In our 5 period MQW test structure (1.55 μm emission wavelength) the well layer strain was held at $\varepsilon_w = +0.9$ % with a layer thickness of $d_w = 10$ nm, the barrier layer strain ε_B was varied from 0 to –1.0 % with $d_B = 8$ nm. Growth temperatures were 600 °C and 470 °C for MOVPE and MOMBE, respectively. The samples were characterized by transmission electron microscopy (TEM), atomic force microscopy (AFM), photoluminescence (PL), high resolution X-ray diffractometry (HRXRD) and broad area test lasers (400 x 100 μm^2 mesa).

For a barrier layer strain of $|\varepsilon_B| \geq 0.4$ % both in MOVPE and MOMBE, wavy MQW interfaces are observed in TEM along with a severe drop in PL intensity and an increase in PL FWHM (full with at half maximum) yielding a significant increase in threshold current density of broad area test lasers. AFM measurements reveal a significant increase in anisotropic surface roughness with increasing strain as shown in Fig. 1, the lateral thickness modulation appears to be much larger in MOVPE than in MOMBE. To obtain flat MQW interfaces and smooth surfaces, the strain energy driven wavy layer growth mechanism must be suppressed. In addition to barrier strain, both, V/III ratio and growth rate, are key parameters for the rate of wavy interface development. Flat interfaces require low V/III ratios and high growth rates. As an example the effect of V/III ratio on HRXRD rocking curves can be seen in Fig. 2 for two cases: (I) $\varepsilon_B = -0.4$ % and (II) $\varepsilon_B = -1.0$ %. Structures with sharper satellite peaks (b) in both cases exhibit much larger PL intensities. Additional improvements in interface quality can be obtained by insertion of thin (1 nm) InP intermediate layers, as also known from MOVPE studies (3, 4), and a reduction of the Ga content in the barrier layers to values below 30 %. Wavy interface development is probably caused by lateral composition fluctuations (4), which are induced by V/III ratio controlled island growth. The effect of the growth parameters on interface quality and device performance will be discussed in detail.

References

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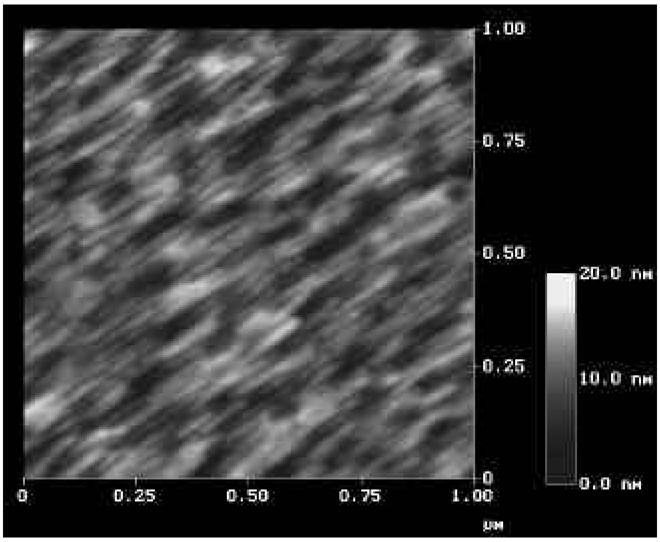

Fig. 1: *Anisotropic surface wavyness of MOMBE grown strained MQW structure with* e_B *= -0.5 %* *(AFM height mapping of topmost layer)*

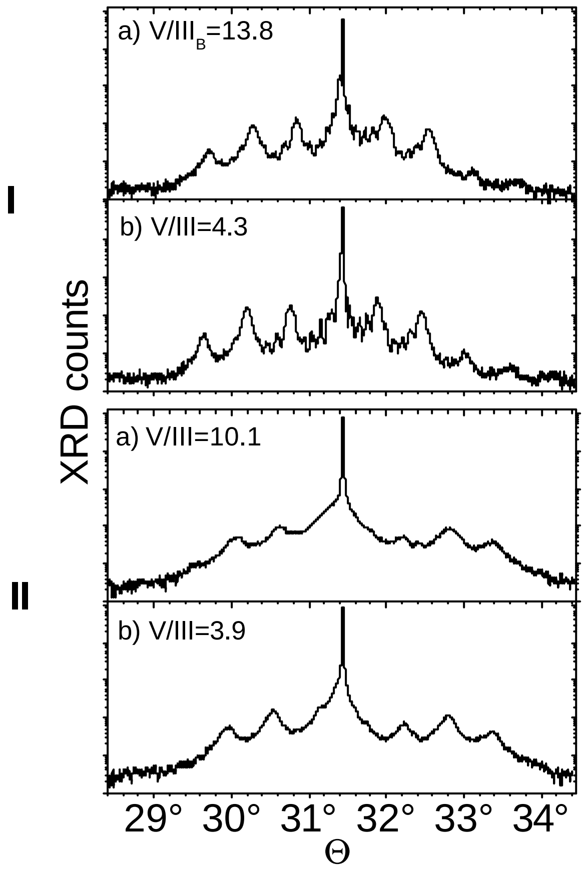

Fig. 2: *Effect of V/III ratio on MQW interface quality in MOMBE (HRXRD rocking curves)*

I) e_B *= -0.4 %*

II) e_B *= -1.0 %*