INVESTIGATION BY SYNCHROTRON RADIATION OF InGaAs LASING STRUCTURES GROWN ON SiGe/Si PSEUDOSUBSTRATES

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ABSTRACT: The growth of highly strained Quantum wells (QWs) on GaAs substrates are facilitated by the initial growth of a linearly graded InGaAs buffer. High-resolution X-ray diffractometry can supply overall information about the quality of the samples while X-ray topography provides both direct evidence of the absence or presence of single defects and visualization of their distribution. We present here a summary of studies performed on these InGaAs/AlGaAs QWs.

Keywords: Synchrotron radiation; pseudosubstrates.

1. INTRODUCTION

Intersubband transitions have been used for applications such as photodetectors, modulators, and nonlinear optics [1-3]. By using InGaAs and AlGaAs for the well and barrier materials, respectively, quantum wells (QWs) can have large conduction band offset, and thus, large intersubband transition energies [4,5]. A series of two samples including an InGaAs layer structure was investigated by X-ray diffraction experiment at University of Linz using a rotating anode source with a conventional laboratory setup and position sensitive detector and at synchrotron source HASYLAB at beam line D4 in Hamburg. A schematic sketch of the sample structure and the nominal structural parameters are shown in Fig.1.

The difference between the samples Ge101 and Ge102 was in the used pseudosubstrate. Sample Ge101 was grown on constant composition Ge/Si(001) pseudosubstrate and Ge102 on constant composition Ge/graded SiGe/Si pseudosubstrate with 6° mis-orientation.
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Fig. 1: Schematic sketch of sample structure of samples Ge101 (constant composition buffer) and Ge102 (graded SiGe buffer).

In order to study the relaxation and strain properties of Ge, GaAs and InGaAs layers, a symmetrical (004) and asymmetrical (224) diffraction reciprocal space maps have been measured in two perpendicular azimuths [6]. The example of XRD reciprocal space maps around the (004) and (224) diffraction for sample Ge101 is shown in Fig. 2.

<table>
<thead>
<tr>
<th>Layer (nm)</th>
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<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>207 GaAs</td>
</tr>
<tr>
<td>2000 Al0.3GaAs</td>
</tr>
<tr>
<td>1.67 GaAs</td>
</tr>
<tr>
<td>8 InGaAs</td>
</tr>
<tr>
<td>1.67 GaAs</td>
</tr>
<tr>
<td>2000 Al0.3GaAs</td>
</tr>
<tr>
<td>1035 GaAs</td>
</tr>
<tr>
<td>374 GaAs HT</td>
</tr>
<tr>
<td>60 GaAs BT</td>
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<tr>
<td>PS</td>
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Fig. 2: Symmetrical 004 (left panel) and asymmetrical 224 (right panel) diffraction reciprocal space maps of the sample Ge101 under two different azimuths, aligned to Ge buffer peak.
2. RESULTS AND DISCUSSION

From the asymmetrical (224) reciprocal space map, we can clearly see that the InGaAs layer is grown pseudomorphically with respect to GaAs/Ge buffer. The detailed analysis of the position of In\textsubscript{x}Ga\textsubscript{1-x}As peak at \(Q_z = (4.380 \pm 0.005) \text{ Å}^{-1}\) gives an average lattice parameter of In\textsubscript{x}Ga\textsubscript{1-x}As layer of \(a_{||} = (5.738 \pm 0.007) \text{ Å}\). Using a dependence of In composition in In\textsubscript{x}Ga\textsubscript{1-x}As alloy on the lattice parameter [8], we get a corresponding In content of \(x = (0.26 \pm 0.04)\).

From the symmetrical (004) reciprocal space map, it is also evident that the InGaAs layer, responsible for lasing emission, exhibits also a lateral periodicity presented by two satellite maxima in distance of \((0.0115 \pm 0.0005) \text{ Å}^{-1}\) from \(0^{th}\) InGaAs peak in \(Q_x\) direction. After analysis, we find out that such position of the maxima correspond to the lateral period of about \((546 \pm 24) \text{ Å}\). This could correspond to the formed island at the InGaAs layer, Fig 3.

![Intensity integrated through lateral maxima over \(Q_z\) direction over interval \(Q_z = (4.315 - 4.410) \text{ Å}^{-1}\).](image)

In order to investigate the strain properties of the GaAs and InGaAs layer more carefully, we have measured also the symmetrical (002) diffraction, see Fig. 4, which is forbidden for Si and Ge but not for the GaAs. Since Ge and GaAs have almost the same lattice parameter, close the (004)
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reciprocal lattice point; the GaAs diffraction signal is disturbed by Ge diffraction signal. In (002) we detect only the signal from GaAs and InGaAs. In the (002) reciprocal space map recorded at HASYLAB beamline D4 in Hamburg, we clearly see the diffraction peak from pure GaAs layers, from InGaAs layer and also a peak at position $Q_z = 2.313 \text{ 1/Å}$ most probably corresponding to the layer with lattice parameter $a_{\text{perp}} = (5.433 \pm 0.010) \text{ 1/Å}$.

Fig. 4: Symmetrical 002 diffraction reciprocal space maps of the sample Ge101.

Fig. 5: Specular reflectivity simulation on the sample structure.
From theoretical simulations it follows, Fig.5, that it is not possible to perform a specular reflectivity measurement in order to obtain information about the interface morphology at InGaAs layer interface and to detect the thin InGaAs layer in reflectivity at all, since the penetration depth is not large enough for grazing incidence angles and usual wavelengths. The InGaAs layer is situated too deep in the structure for XRR investigation [7,8].

REFERENCES