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Growth of strained GaAsSb layers on GaAs (0 0 1) by MOVPE

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Abstract

We investigated the growth of GaAsSb layers and quantum wells (QW) on GaAs (0 0 1) by MOVPE. Sb concentrations up to 12% were achieved at low arsine partial pressure and low growth temperature. Varying the trimethyl antimony pressure primarily changed the growth rate but not the Sb incorporation. The in situ reflectance anisotropy spectrum during growth resembles that of a GaSb surface. Sb has a strong tendency towards segregation and is only incorporated after reaching a certain critical surface coverage. These findings can be explained by a very mobile and highly Sb enriched surface layer which forms by surface melting due to strain.

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1. Introduction

For the growth of laser structures (especially vertical-cavity surface-emitting lasers) with an emission wavelength of 1.3 μm, GaAs as a substrate is advantageous in comparison to InP, which is normally used in this wavelength range, because of better material properties and the more mature device technology in the GaAs system. Using InGaAsN as the active region, this goal has been recently achieved [1]. However, metal-organic vapour phase epitaxy (MOVPE) of this N-containing material is difficult, since a low growth temperature is needed for high N incorporation [1,2] which directly contradicts good precursor decomposition. Therefore, we investigated GaAsSb as an alternative material for the active region.

Unfortunately, there are very few reports in literature for the MOVPE growth of GaAsSb. The ternary $GaAs_{0.53}Sb_{0.47}$ is lattice matched to InP

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and mostly used for solar cell or hetero-bipolar transistor applications. For the growth of strained GaAsSb layers on GaAs the need for low V/III ratios to achieve reasonable Sb incorporation was already emphasised in previous works [3–8]. Recently, in situ studies of GaAs and GaAsSb surfaces [9] were reported using reflectance anisotropy spectroscopy (RAS). The growth of GaAsSb multiple quantum well structures was monitored too. In some cases the Sb containing layers were grown just by supplying tri-methyl Sb before the actual growth [10]. This effect demonstrated the strong segregation of Sb during growth even at relatively low temperatures. Strong segregation and growth delay effects were also reported previously in molecular beam epitaxy (MBE) [11,12].

2. Experimental procedure

The GaAsSb layers were grown on GaAs (0 0 1) 2° [1 0 0] epi-ready substrates in a horizontal double-wall rotating disk quartz reactor (Aixtron 200/4). Sources used were tri-methyl gallium (TMGa), tri-methyl antimony (TMSb), and arsine, the carrier gas was hydrogen at 15 kPa. If not stated otherwise the growth temperature was 510 °C.

The growth was monitored in situ by reflectance anisotropy spectroscopy (RAS or sometimes called RDS). Ex situ characterisation was done using X-ray diffraction (XRD), and photoluminescence (PL) at room temperature.

3. Results

The few studies available on MOVPE growth of GaAsSb on GaAs indicate that a rather low arsine partial pressure is needed to achieve at least a small Sb incorporation [3–8]. Bedair et al. [5] especially noted that the arsine partial pressure was the crucial parameter, rather than the TMSb partial pressure. Our findings agree with this. Even increasing the TMSb partial pressure to unreasonably high values like 50 Pa did not lead to an incorporation above 2% Sb. Doubling the V/III ratio led to a small decrease in Sb incorporation, which somehow disagrees with Ref. [7]. However, this might be due to different Ga and As precursors (tri-ethyl gallium (TEGa) and tertiary-butyl arsine (tBAs)) in that study. Since a very low AsH_3 partial pressure is needed to achieve reasonable Sb incorporation the overall V/III ratio must be very low. Therefore, the surface is saturated with methyl groups from TMGa and TMSb decomposition. Since the desorption of methyl groups is limiting the growth rate, the supply of additional methyl groups by raising TMSb partial pressure further reduces the growth rate. Hence, in our studies increasing the TMSb partial pressure beyond the TMGa partial pressure decreased the growth rate (see Table 1) and sometimes slightly decreased the Sb incorporation. Thus, after the initial studies most layers were grown with a TMSb/TMGa ratio close to unity.

The right side of Fig. 1 shows the RAS spectra during TMSb exposure and growth at the most extreme conditions in our series of experiments. The spectra during growth of GaAsSb with TMSb

Table 1
Comparison of different GaAsSb QWs grown using 2.0 Pa AsH_3 at 510 °C embedded in 20 nm $GaAs_{0.84}P_{0.16}$

No.	Growth time (s)	TMGa (Pa)	TMSb (Pa)	GaAs (nm)	$GaAs_{1-y}Sb_y$ (nm)	y(Sb)	Growth rate (nm/s)
A829	4400[a]	0.95	1.0	??	122	0.092	0.029
A869	48	0.75	0.7	3.2	1.5	0.02	0.098
A870	309	0.5	0.5	4.7	5.3	0.04	0.032
A900	309	0.5	1.0	3.0	4.8	0.043	0.025
A898	618	0.5	0.67	7.3	10.5	0.05	0.029
A899	1236	0.5	0.67	7.3	28	0.035	0.029

[a]Thick layer without GaAsP barriers.