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Structural and optical studies of GaBiAs layers grown by molecular beam epitaxy on (311)B and (001) GaAs substrates

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Outline

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- Growth on non-conventional GaAs substrates [non-(100)]
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- Structural characterisation of (100) and (311)B GaAsBi epilayers
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Motivation

$GaAs_{1-x}Bi_x$ and $GaN_yAs_{1-x-y}Bi_x$ alloys are attracting a considerable deal of attention due to their remarkable properties and potential applications.

Properties

- Large bandgap reduction (~100 meV per % of N; ~90 meV per % of Bi)
- Strong enhancement of the spin-orbit splitting energy

Applications

- Solar cells
- Infra-red lasers
- Terahertz emitters and detectors
- Spintonics
- Heterojunction bipolar transistors
- Temperature-insensitive semiconductor band gap

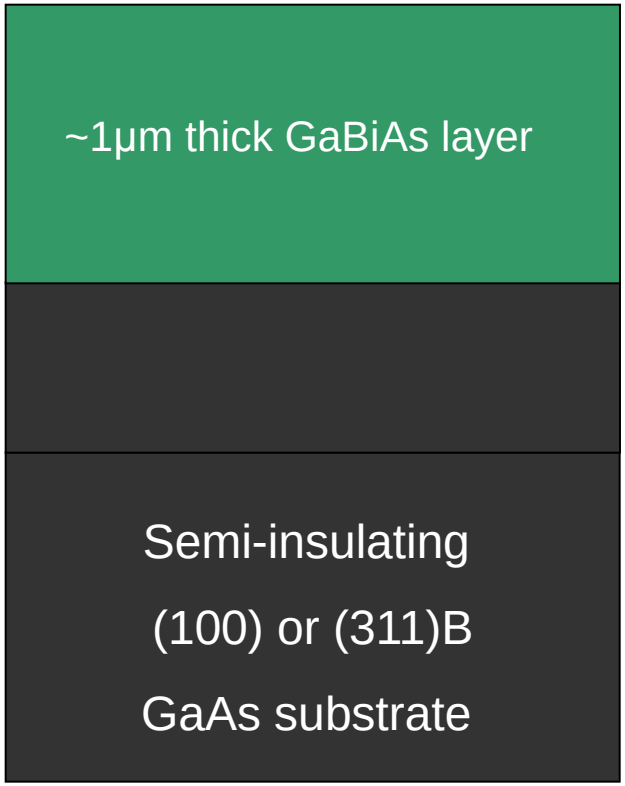
Growth on non-conventional GaAs substrates

An important degree of freedom in the epitaxy of III-V semiconductors is the growth of layers on high Miller index surfaces, *i.e.* **surfaces oriented differently from the usual (100) orientation.**

The use of non-(001) substrates has allowed:

- Fabrication of ultrahigh mobility two-dimensional hole gases in GaAs/AlGaAs heterostructures
- High-performance InAs/GaAs quantum dot QD lasers
- InGaAs/GaAs QDs with enhanced piezoelectric effects
- GaMnAs epilayers with modified Mn incorporation and magnetic anisotropies

Samples Details

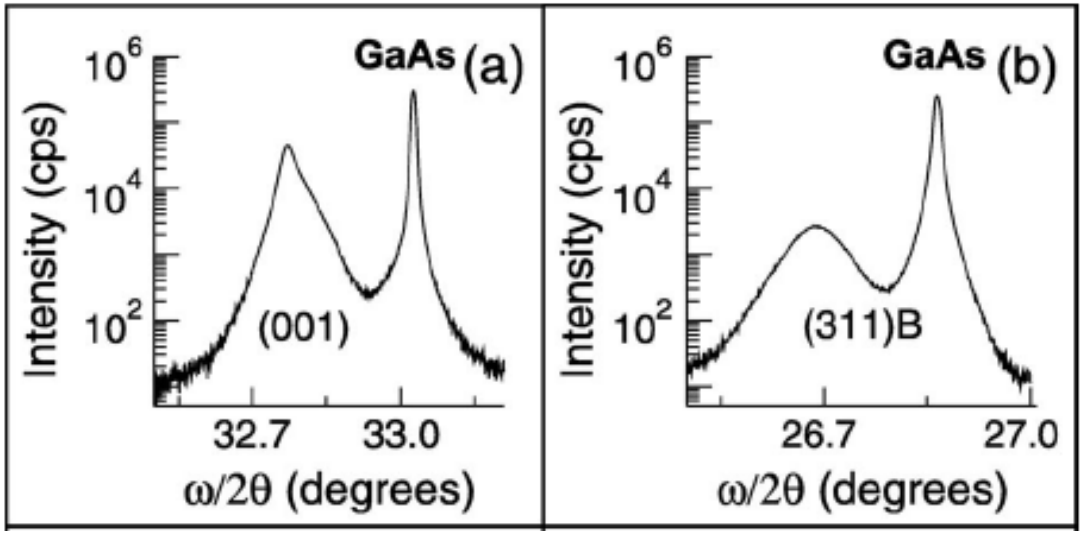


	Ms-819	Ms-821	Ms-820	Ms-822
	(100)	(100)	.(100)	(100)
Growth T (°C)	~350	~350	~350	~350
As (Torr)	~1.2 10^{-5}	~1.0 10^{-5}	~8.0 10^{-6}	~6.0 10^{-6}
Bi (Torr)	~1.2 10^{-7}	~1.2 10^{-7}	~1.2 10^{-7}	~1.2 10^{-7}
			This is the region of near stochiometric growth	

	Ms-823	Ms-825	Ms-824	Ms-826
	(311)B	(311)B	(311)B	(311)B
Growth T (°C)	~350	~350	~350	~350
As (Torr)	~1.2 10^{-5}	~1.0 10^{-5}	~8.0 10^{-6}	~6.0 10^{-6}
Bi (Torr)	~1.2 10^{-7}	~1.2 10^{-7}	~1.2 10^{-7}	~1.2 10^{-7}
		This is the region of near stochiometric growth		

Growth Temperature = 350^{0}C
Growth rate of GaAs = 1 monolayer per second
Bi flux constant = 1.2 10^{-7} Torr
As flux varied = 1.2x10^{-5} -6x10^{-6} Torr

HRXRD Results

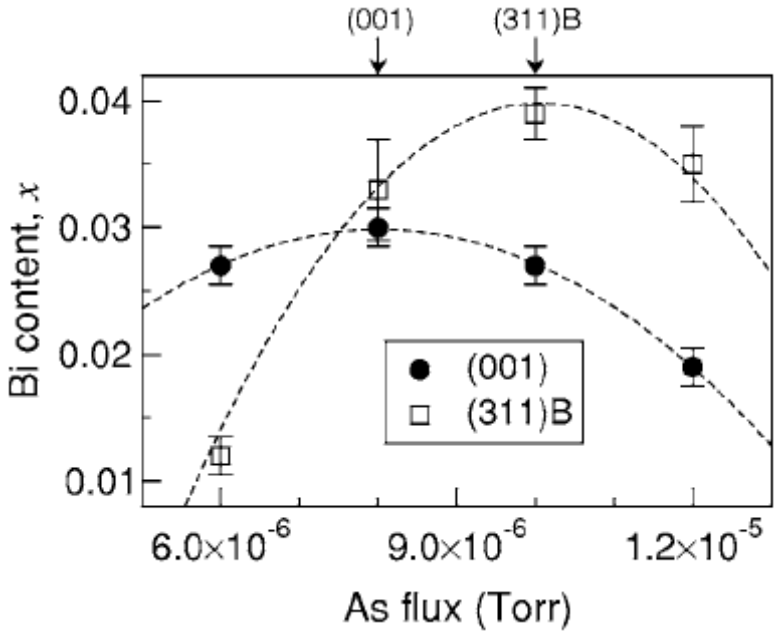


(001) and (311)*B* GaBiAs epilayers grown under near-stoichiometric conditions

- Reflections arising from the GaAs substrate
- Broad diffraction peak at lower diffraction angles. This peak is attributed to the GaBiAs alloy

Similar patterns were obtained for the other samples with different Bi content

Effect of the Arsenic Overpressure on the Bi incorporation in (001) and (311)B GaAs epilayers



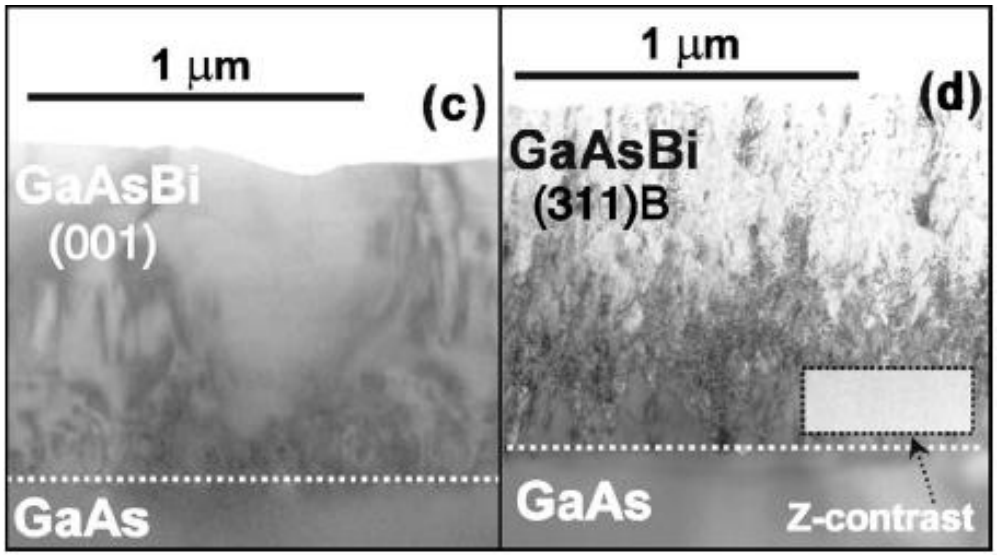
• Bi content incorporated into all (311)*B* epilayers, (with the exception of the sample grown with the lowest As flux), is appreciably larger than that incorporated into the (001) samples.

• Near stoichiometric growth conditions

Bi content in (311)B = 4%

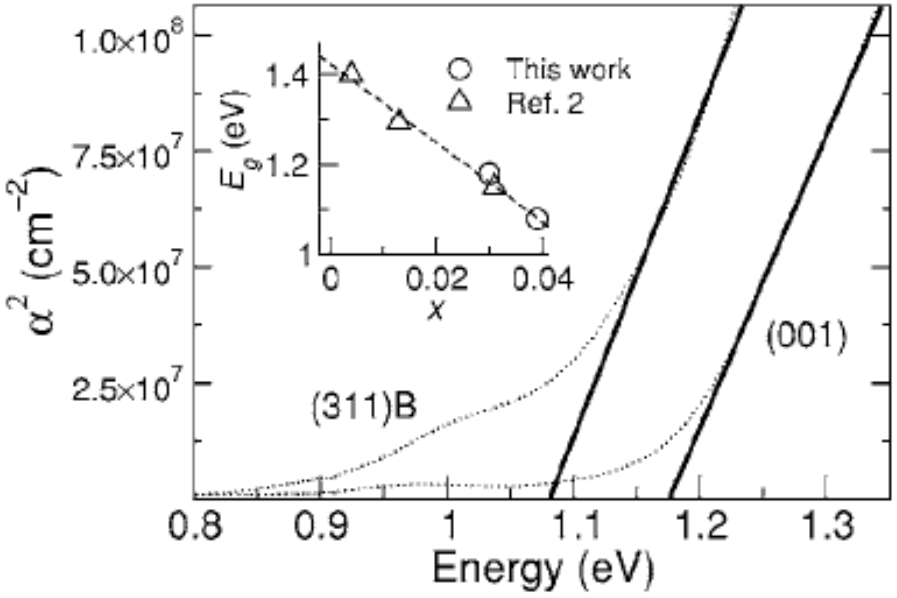
Bi content in (001) = 3%

Cross sectional view of Bright Field TEM Images



- Presence of extended structural defects in both epilayers.
- For (001) GaBiAs film, such defects consist mainly of dislocations.
- For (311)*B*, crystalline quality of the GaBiAs epilayer is fairly good close to interface but it degrades closer to free surface.
- For both orientations the *Z*-contrast image close to the interface reveals that no extended Bi segregation exists in these epilayers.

Optical transmission spectroscopy results



ΔEg ~ 90 meV per 1% of Bi

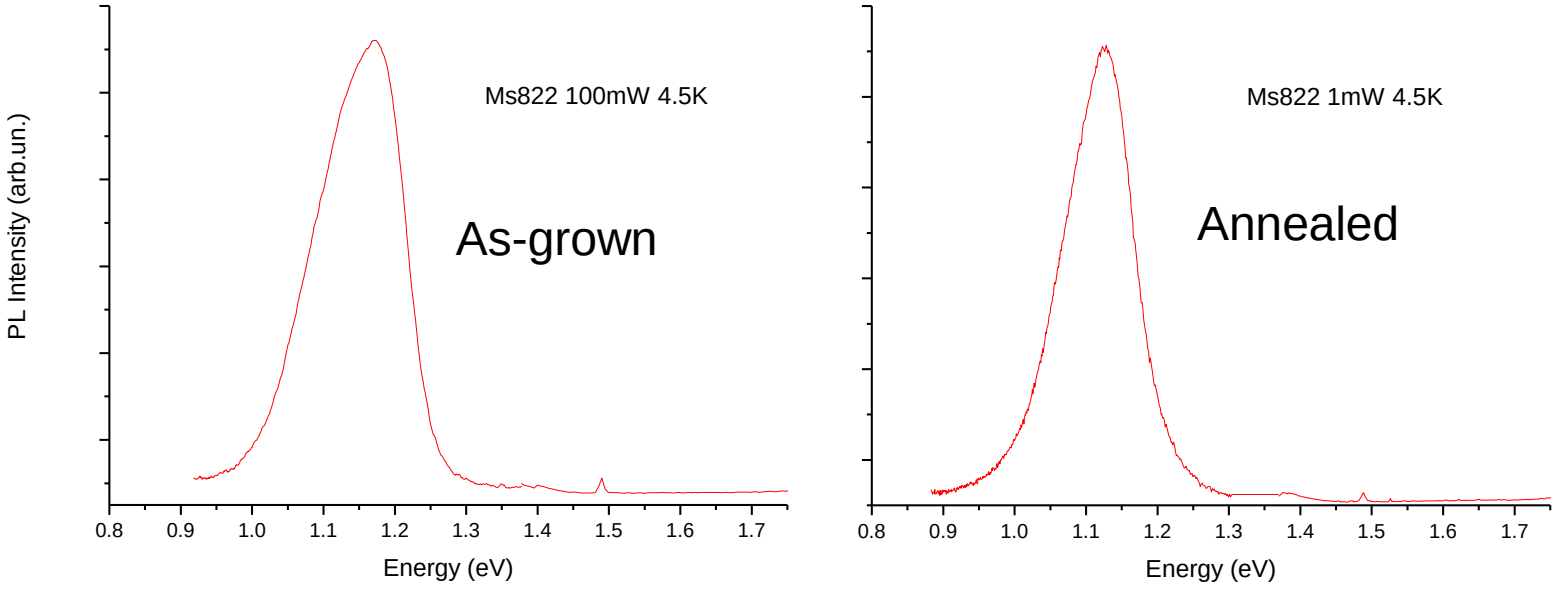
Samples grown near stoichiometric growth conditions:

For (001): Eg= XXX eV
For (311)B: Eg= XXX eV

For the same Bi flux the (311)B Eg is around 90 meV lower than for the corresponding (001) Eg

Effect of Annealing: (100) samples

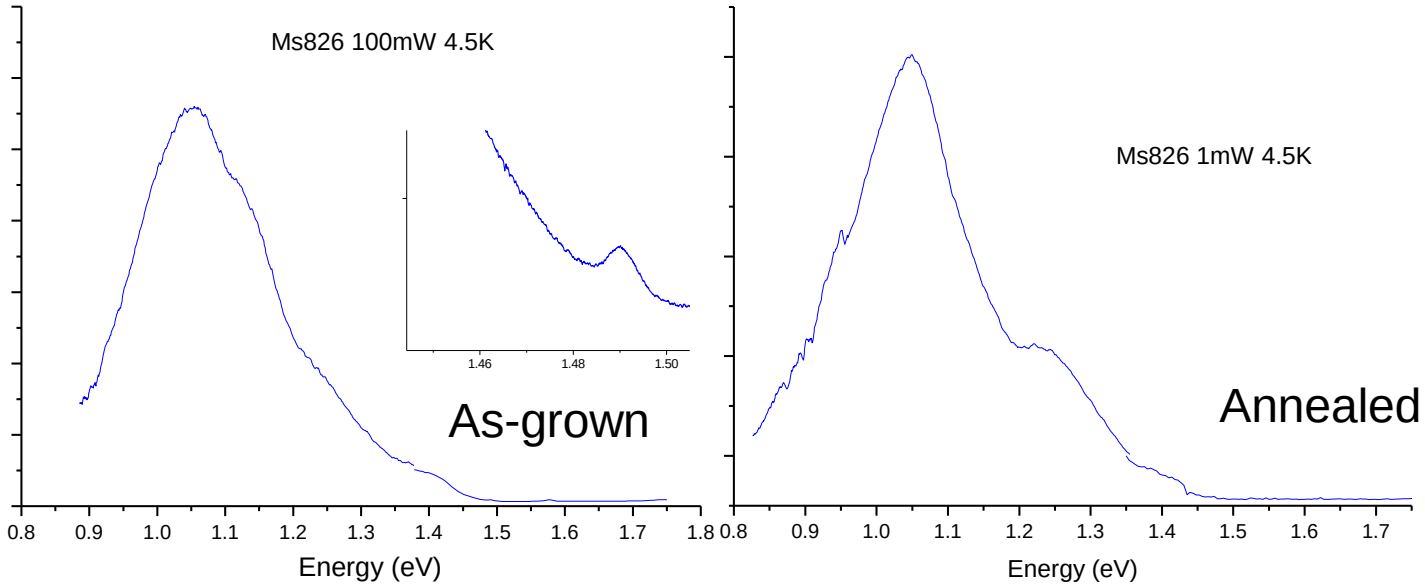
annealed at 200 ^{0}C for 3hours



- PL peak position does not change after annealing: 1.17eV
- PL linwidth is slightly narrower (~70meV)
- Emission is enhanced

Effect of Annealing: (311)B samples

annealed at 200 ^{0}C for 3hours



- Emission is enhanced
- PL peak position does not change after annealing: 1.05eV
- PL linewidth is slightly narrower; PL band shape is changed

Conclusions

- Content of Bi in GaBiAs varies with As flux.

- Enhancement of Bi incorporation was obtained by using (311)B GaAs substrate

near stoichiometric growth conditions and constant Bi flux:

x~ 4% for (311)B and x~3% for (001)

- Bi incorporation into GaAs leads to large energy band gap reduction.

ΔEg ~ 90 meV per 1% of Bi.

- Enhancement of PL after annealing at 200 C for 3 hours.

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