Cathodoluminescence characterization of the band gap energy in dilute nitride GaNSbAs alloys

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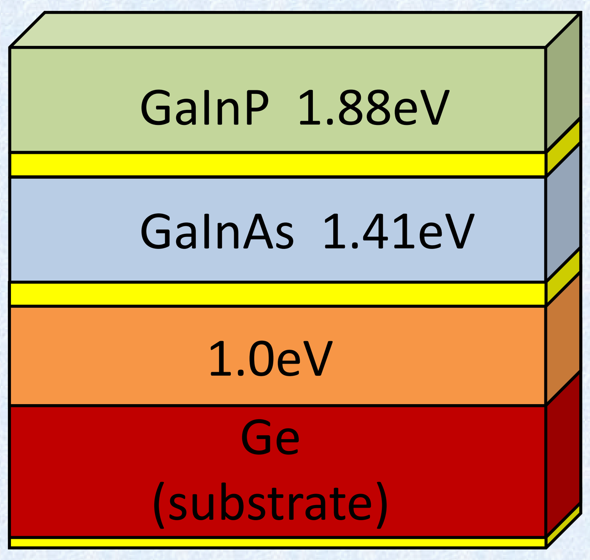
Motivation



The development of a high quality 1eV material is one of the most import challenges in high efficiency solar cells development. The GaInP/GaInAs/1eV/Ge structure attained one of the highest solar cell efficiency, 44.0%. The dilute nitride GaNSbAs has attracted a considerable interest, since this alloy can be grown lattice-matched to GaAs with a bandgap of 1eV. However, It is well-known that N incorporation in dilute nitrides is associated with the generation of structural defects and as a result, the degradation of the optical properties. Thermal annealing is the most common procedure to improve the dilute nitrides response. In order to have a deeper understanding of the GaNSbAs layer behaviour, the effects of ex-situ annealing in N-atmosphere and in-situ annealing in As-atmosphere, have been investigated. Samples have been analysed for the first time by cathodoluminescence (CL), being this technique a good method for getting direct information in a simple, fast and non-destructive way about compositional gradients. It has been supported by scanning transmission electron microscopy (STEM) and energy dispersive spectroscopy (EDS).

Experimental

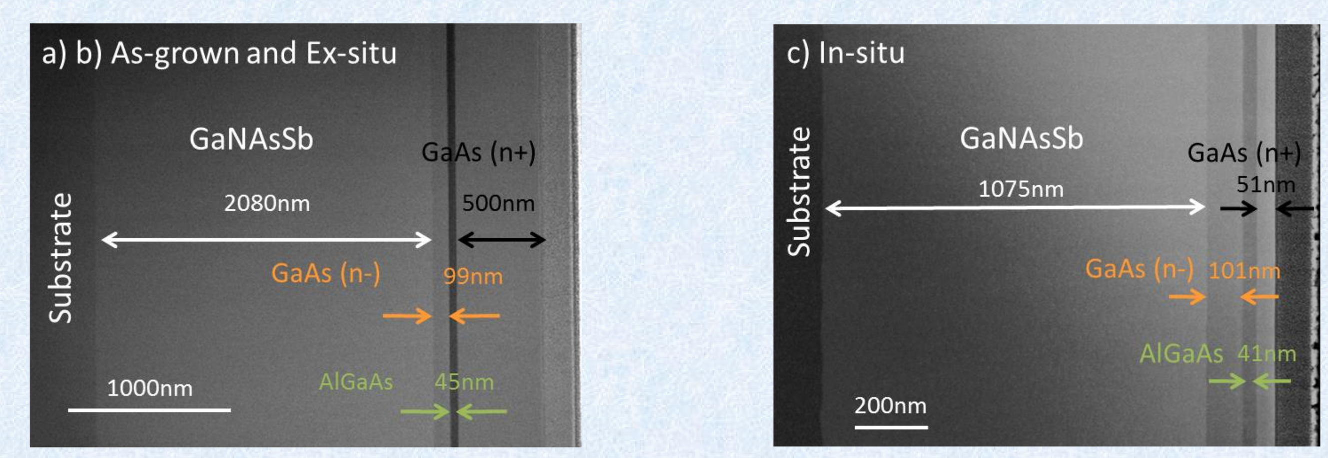
Three samples of $GaN_xSb_yAs_{1-x-y}$ (0<x <0.05, 0<y<0.1) have been grown on top of a GaAs (100) substrate by molecular beam epitaxy (MBE). They have been analyzed by STEM and EDS. The optical properties were measured by CL in both, plan view and cross-section.

Theoretical Thickness

As-grown, Ex-situ	Layer	In-situ
500nm	GaAs (n+)	50nm
50nm	AlGaAs (n+)	50nm
50nm	GaAs (n-)	50nm
2000nm	GaNAsSb	1000nm

Samples	Thermal Treatment	Thickness of the GaNSbAs (nm)
As-Grown	----	2000
Ex-situ	N_2 at 750°C	2000
In-situ	As at 700°C	1000

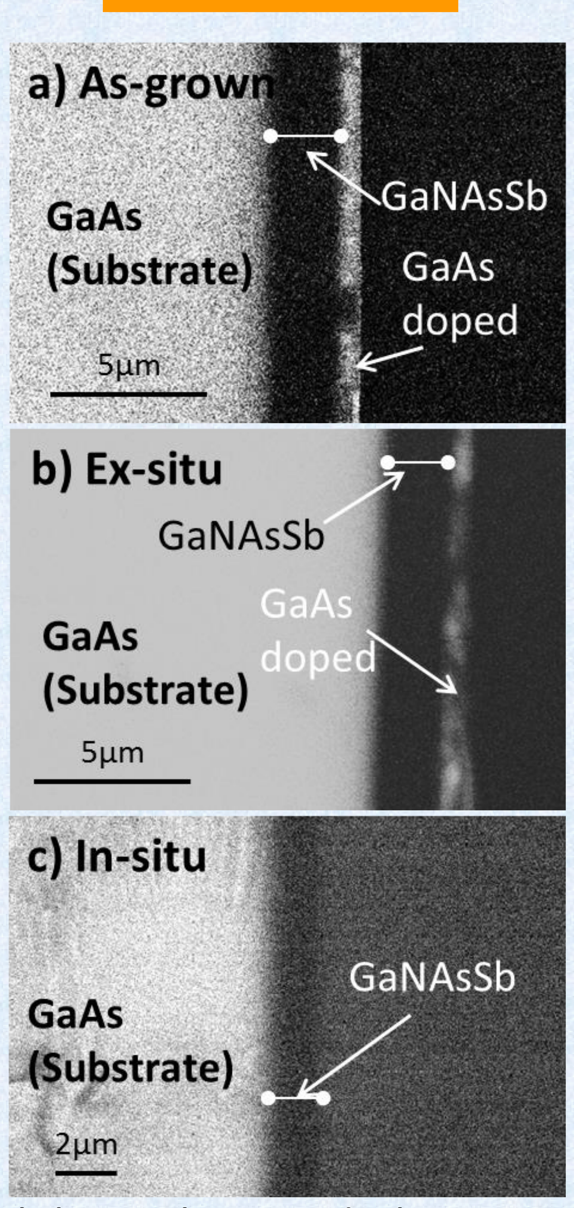
STEM



Interfaces appear flat and sharp and no noticeable roughness is observed in any of them, independently of the annealing process.

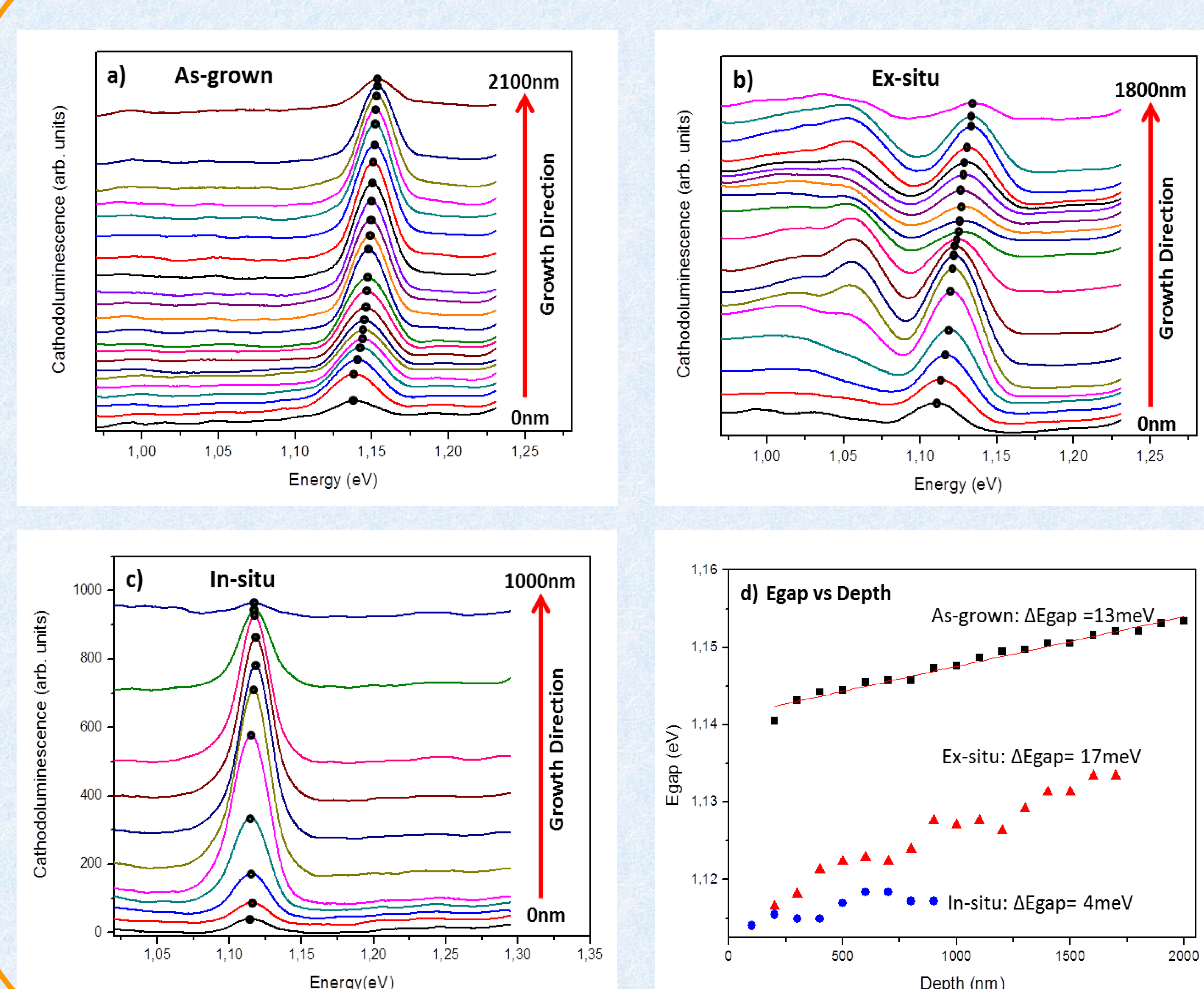
Results

Image CL



GaNAsSb layer shows a dark contrast. Both, As-grown and Ex-situ, GaAs doped layers are not homogeneous. In the In-situ doped layers the thickness impede homogeneity observations.

Spectral CL in Cross-Section



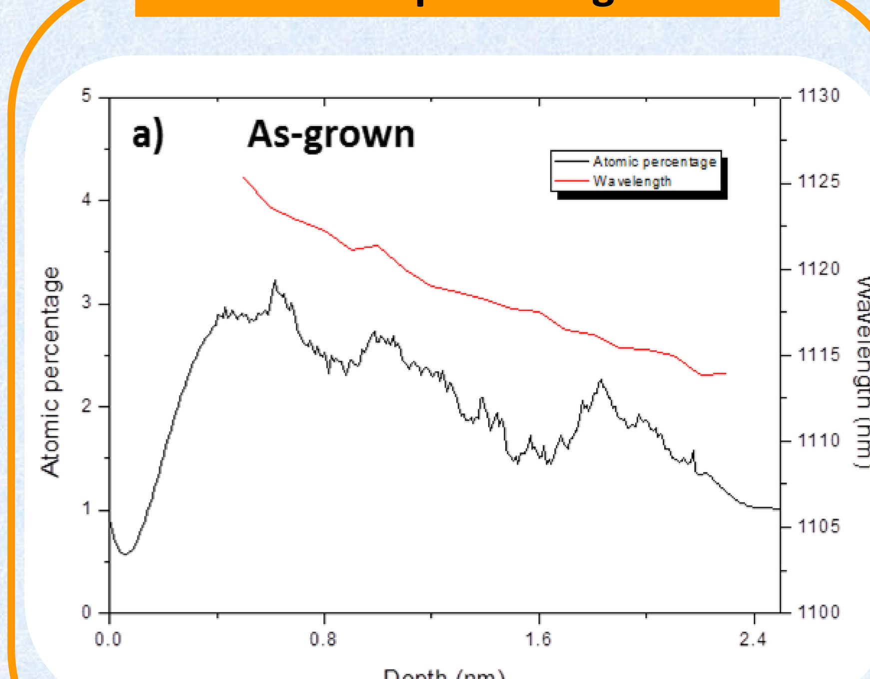
- As-Grown sample shows an almost linear CL peak displacement. Ex-situ and In-situ annealed samples reveal a non-linear band gap energy shift.
- Regarding the As-grown sample, a CL peak displacement towards lower band gap energies was observed, for both, Ex-situ and In-situ annealed samples.
- In Ex-situ annealed samples the CL spectra shown an additional, defect related band, in the low energy tail of the band-to-band CL peak, around 1.05eV.
- The band gap energy increases in the growth direction in all cases.
- In-situ annealed samples had the smallest variation in the band gap energy.

Discussion and Conclusions

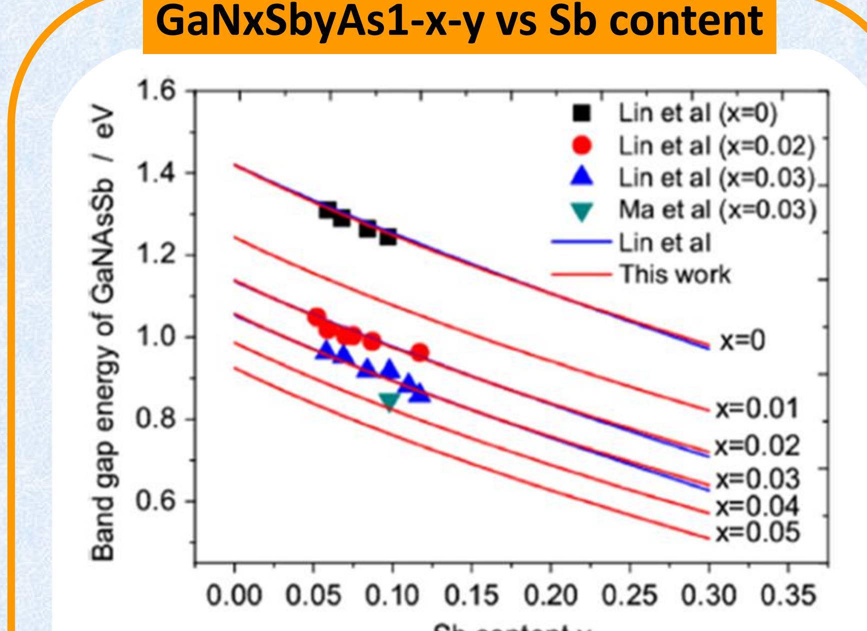
- **Band gap energy shift along the growth direction**
  1) **Strain:** is neglected since samples are lattice matched.
  2) **Composition (Sb and N)**
     - As-grown: The observed reduction in the atomic percentage of Sb support the reduction in wavelength and therefore the shift to higher band gap energies.
     - Annealed (Ex-situ and In-situ): No variations in Sb at.% are observed. The shift on the band gap energy can be attributed only to the local N-fluctuations.

- **Redshift of the band gap energy with annealing**.
- **In-situ** samples: The **band gap energy,** was nearer to the target value (1eV) and shows the lower **compositional fluctuations.**

EDS: atomic percentage of Sb



Band gap energy of GaNxSbyAs1-x-y vs Sb content



*Zhao c-Z, Guo H-F, Wei T, Wang S-S and Lu K-Q, 2016 Physisca B 485, 35-38.

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