Optical Properties of GaAsN Single Layers and GaAsN/InAs/GaAs Superlattices studied by Spectroscopic Ellipsometry (G6.35)

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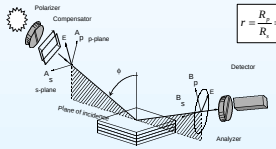
Outline

- We present dielectric functions of $GaAs_{1-y}N_y$ ($0\% \le y \le 3.7\%$) for wavenumbers from 100 cm^{-1} to 600 cm^{-1} and for photon energies from 0.75 eV to 4.5 eV.
- For 0.75 eV $\le E \le$ 4.5 eV we compare our model dielectric functions (MDF) with wavelength by wavelength inverted ellipsometric data.
- We perform two critical point (CP) analysis for the band gap and the E_1 and $E_1+\Delta_1$ transitions and calculate the effect of biaxial strain onto the latter.
- We analyse energy and amplitude of the GaN sublattice resonances in the GaAsN sublayers of our compressive and tensile strained superlattices.

Spectroscopic-Ellipsometry (SE)

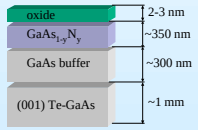


$$r = \frac{R_p}{R_s} = \left(\frac{E_p^{ref}}{E_p^{inc}}\right) \Big/ \left(\frac{E_s^{ref}}{E_s^{inc}}\right) = \tan\Psi \exp(i\Delta)$$

Samples

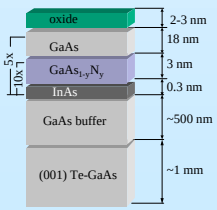
® MOVPE, T=525 C
® precursors: TMGa , TBAs, DMHy

Single Layers

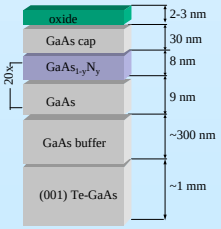


Superlattices

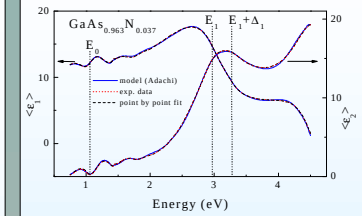
compressive

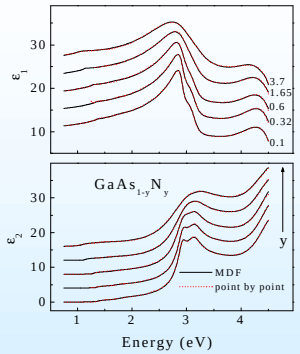


tensile



Modelling the dielectric function of GaAsN single layers for 0.75 eV £ *E* £ 4.5 eV



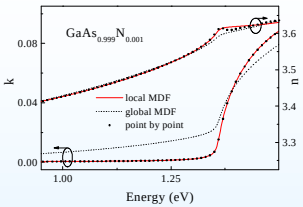


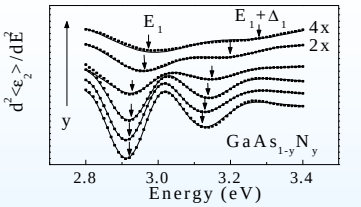
For photon energies ranging from 0.75 eV to 4.5 eV we performed point by point inversion of our experimental Ψ and Δ spectra, and additionally we provide model dielectric functions (MDF's). In the above figure we compare the results of both analysis for sample $GaAs_{0.963}N_{0.037}$. The red dotted lines refer to the experimental pseudodielectric functions <ε>, and the blue straigth (black dashed) lines to the best fit model (point by point) spectra. Notice the good agreement between all three spectra.

We employ Adachi's critical-point composite model[1] for parameterization of the $GaAs_{1-y}N_y$ dielectric function $e(E)$ for photon energies ranging from 0.75 eV to 4.5 eV. Adachi's MDF is based on the one-electron interband-transition approach, and includes terms for the E_0, $E_0+\Delta_0$, E_1, $E_1+\Delta_1$ transitions, and phenomenological terms that describe contributions from higher-lying direct transitions.

[1] S. Adachi, *Physical properties of III-V semiconductor compounds* (Wiley, New York, 1992).

Critical point analysis for the E_0, E_1 and E_1+D_1 transitions

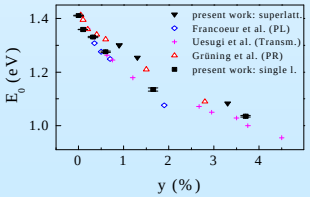




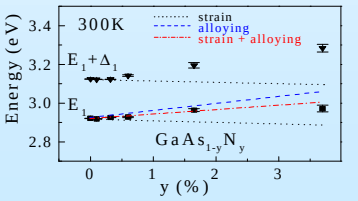
Our global model gives too large absorption indices below the bandgap (see Fig. above). Thatswhy we employed a different (local) MDF for energies from 0.75 eV to 1.5 eV that agrees well with the point by point extracted optical constants.

Local MDF

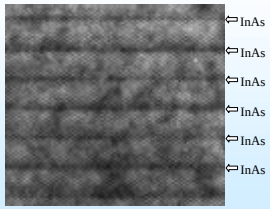
$$e_{loc}(E) = e^{E0}_{Adachi}(E) + e^{E0+\Delta0}_{Adachi}(E) + \frac{A_{pole}}{E^2_{pole} - E^2}$$



Our CP analysis reveals blueshift of the E_1 and $E_1+\Delta_1$ transitions. The black dotted lines in the Fig. below have been calculated using deformation potential theory and depict the effect of biaxial strain in the growth plane. Knowing the E_1 energy of cubic GaN (7.0 eV) the red line has been calculated as the sum of the effects of strain and alloying, and fits the blueshifted E_1 energies up to y = 1.65%.

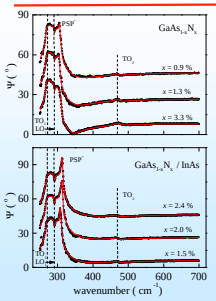


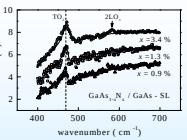
TEM cross section of SL

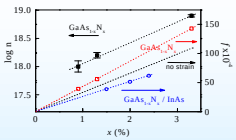


TEM: Dr. G. Wagner @ Institut for Surface Modification Leibzig, Germany

GaN-sublattice resonance of superlattices







n … carrier conc.
$f = (\omega_{LO2} - \omega_{TO2})/\omega_{TO2}$

Our GaAsN sublayers show two-mode behaviour for infrared wavelengths [ω_{TO1}(GaAs) ≅ 268 cm^{-1} and ω_{TO2}(GaN) ≅ 470 cm^{-1}]. The amplitude f of the GaN resonance increases linearly with the nitrogen composition x but with different slopes for the two different strain states in the two types of superlattices. This can be used to monitor strain or nitrogen composition in GaAsN layers. We further detect free carriers within the GaAsN sublayers of the superlattices without InAs. This goes along with an improved morphology of the GaAsN sublayers of the SL's with InAs.

Dielectric function from far-IR to UV