Surface electron accumulation and effective mass anisotropy in wurtzite structure InN

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Our message

- MO generalized ellipsometry measurements show evidence for a thin electron accumulation layer and corroborate HREELS and C-V data
- Bulk and surface electron concentration follow power law dependencies as a function of the InN layer thickness
- Strong deviation of scaling factors of the true bulk electron concentration and counted dislocation densities suggests evidence for a new defect related doping mechanism – most likely point defects, previously thought to be thickness independent
- Neutralization of surface donors might be easier for low background concentrations
- Experimental evidence for α-InN 1-point effective electron mass value for polarization perpendicular to c-axis: m = 0.055 ± 0.03 m₀ and m⊥ = 0.037 ± 0.03 m₀

Band gap

Experimental and theoretical evidence for E_g(InN) = 0.7 eV – 1-point effective mass has been overestimated

m⊥ ≠ m₀

Anisotropic 1-point effective mass predicted

Non-parabolic cond. band

Non-parabolic conduction band – effective mass depends on the free-charge-carrier concentration

Surface accumulation

Electron surface accumulation obscure electrical, contact-based measurements – true bulk electron concentration is unknown

Far-infrared magnetooptic generalized ellipsometry

Contact less, non-destructive determination of phonon and free-charge-carrier parameters (concentration, effective mass, mobility) in thin layer samples by stratified dielectric model calculation

Recent publications on MO generalized ellipsometry:

Δ = 10°

Experiment and theoretical data: E_g(InN-1) = 0.7 eV

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| D. Ellez et al., PSS B 63, 1024 (2003) |

Motivation: electronic properties of InN

Standard ellipsometry (zero-magnetic-field)

Electron surface accumulation or depletion?

Wallpaper: m = 0.055 ± 0.03 m₀ and m⊥ = 0.037 ± 0.03 m₀

Magnetooptic generalized ellipsometry

Differences between Mueller matrix data (chiral elements M₁₁, M₁₂, M₁₃, and M₂₃) measured magnetic fields of +4.5 T and -4.5 T. The non-chiral elements M₁₂, M₁₃, and M₂₃ vanish.

Bulk- and surface carrier properties

- Bulk- and surface carrier concentration follow the same power-law dependencies as a function of the InN layer thickness
- The observed scaling factor deviates strongly from the scaling factor for threading dislocations: the most dominant thickness dependent donor:
  \[ \alpha_{\text{InN}} = -1.92 \pm 3.7 \quad \alpha_{\text{InN}} \]
- Other thickness dependent donors must be present

Anisotropic 1-point effective mass

Anisotropy corresponds with recent ab initio band-structure calculations:

- Calculated: 14%  this work: 17% 
- Application of Kane's two-band model: 0.055 m₀ > m* > 0.037

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