Introduction

Lattice vibrations and free-carrier absorption dominate the infrared dielectric response of thin-film semiconductor heterostructures. Infrared Spectroscopic Ellipsometry (IRSE) determines thin-film lattice modes and coupled phonon-phonon modes of (Al,Ga)N- and InN-based materials. IRSE analysis of simple heterostructures establishes an infrared dielectric function database, which allows the simultaneous analysis of

- carrier properties (mobility and concentration) in p- and n-type doped device regions,
- morphology (composition and crystal quality), and
- strain in complex optoelectronic and electronic semiconductor device structures.

Infrared Ellipsometry

Instrumentation

- Arbitrary-anisotropic layered materials,
- Ti, Mg, Au, Ge, Pt, Cr, Pd, Pt.

The objective of ellipsometry is to determine the complex dielectric function

\[ n = n_0 + i n_1 \]

and the complex reflection coefficient

\[ R = R_0 + i R_1 \]

The data are fit to the Fresnel equations and have the form

\[ R = \frac{(n - 1) / (n + 1)}{(n - 1) / (n + 1)} \]

Data Analysis

- Fits procedure
- Data analysis
- Comparison to experiment

Phonon modes of hexagonal and cubic group-III-nitrides

Strain and composition

Surface carrier depletion layer

Effective carrier masses

We have determined the following values so far:

- in-GaN: n = 2.02 ± 0.005 cm⁻³
- in-GaN: m = 0.005 ± 0.000 cm⁻³

AlGaN / GaN superlattice structure

Group-III-nitride LED structure

Group-III-nitride laser diode structure

Assumptions

- no free carriers in AlGaN barriers:
  \( p_n = 0 \text{ cm}^{-3} \), free q.
- GaN, \( p_n = 0 \text{ cm}^{-3} \)
- no free carriers in AlGaN barriers:
  \( n_n = 0 \text{ cm}^{-3} \)

IRSE results

- \( p_n = 4.7 \times 10^5 \text{ cm}^{-3} \)
- \( n_n = 2.2 \times 10^5 \text{ cm}^{-3} \)

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- \( n_n = 2.2 \times 10^5 \text{ cm}^{-3} \)

Assumptions

- \( n_n = 3.9 \times 10^5 \text{ cm}^{-3} \)
- \( p_n = 2.2 \times 10^5 \text{ cm}^{-3} \)

IRSE results

- \( N_n = 3.9 \times 10^5 \text{ cm}^{-3} \)
- \( N_p = 2.2 \times 10^5 \text{ cm}^{-3} \)

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