UNIVERSITÄT LEIPZIG

Far-infrared dielectric functions and phonon modes of spontaneously ordered $(Al_xGa_{1-x})_{0.52}In_{0.48}P$

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TuP G07

Our Messages

Far-infrared spectroscopic ellipsometry (FIR-SE):

FIR-SE is an extremely valuable tool for studying optical (structural and electrical) properties of III-V semiconductor layer structures. Exact knowledge of phonon and free carrier properties of multinary alloys is very important for tailoring material's properties in device engineering but often not available.
The fir-dielectric function of spontaneously (partially) CuPt-ordered AlGaInP has tensor character. The phonon modes with A_1 and E-symmetry in quaternary CuPt-ordered $(Al_xGa_{1-x})_{0.52}In_{0.48}P$ are determined employing FIR-SE.

Observation:

Ternary and quaternary III-V-semiconductor alloys (here: AlGaInP) have ir-active lattice modes with small polarity which can not be assigned to the binary constituents.

Conjecture:

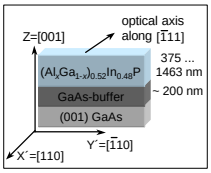
Locally the bonding relationship (segregation, partial local ordering) fluctuates and induces lattice modes of small polarity (alloy-induced modes: AM) in the alloy.

Evidence:

The alloy-induced modes show an increasing directional response (anisotropy, transition to C_{3v}-symmetry) and polarity (TO-LO splitting) with increasing degree of ordering.

Experiment

- MOCVD:
  - T_G=720°C
  - $(Al_xGa_{1-x})_{0.52}In_{0.48}P$ unstrained on (001) GaAs:Te substrate with different misorientations
  - Al-content x=0, 0.32, 0.7, and 1
- TEM:
  - domain structure
  - CuPt-ordering
- UVVIS-SE:
  - layer thickness, band-band transitions
  - degree of ordering
- FIR-SE:
  - phonon modes and anisotropy



model dielectric function:

Infrared active lattice modes

$$\varepsilon^{(L)} = \varepsilon_\infty \prod_{j=1}^{n} \frac{w^2 + ig_{LO,j}w - w_{LO,j}^2}{w^2 + ig_{TO,j}w - w_{TO,j}^2}$$

Alloy induced modes (TO-LO << TO, LO)

$$\varepsilon^{(L+AM)}(w) = \varepsilon^{(L)}(w) \prod_{k=1}^{m} \left(1 + \frac{idg_k\, w - dw_k^2}{w^2 + ig_{AM,k}w - w_{AM,k}^2} \right)$$

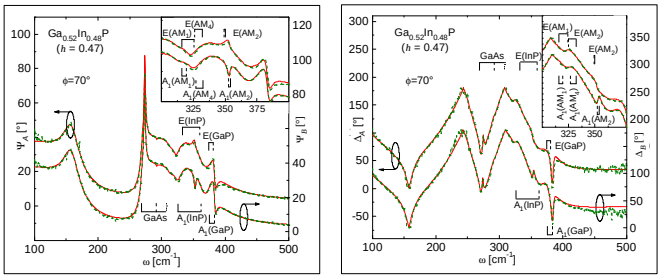
Two FIR-SE measurements at different sample orientations provide of the anisotropic dielectric function tensor:

Setup A:
Plane of incidence *perpendicular* to [110]

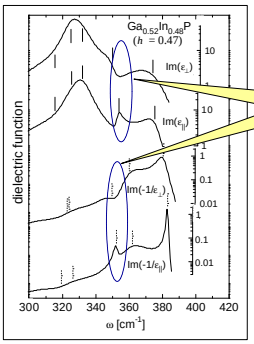
Setup B:
Plane of incidence *parallel* to [110]

$Ga_{0.52}In_{0.48}P$

FIR-SE analysis



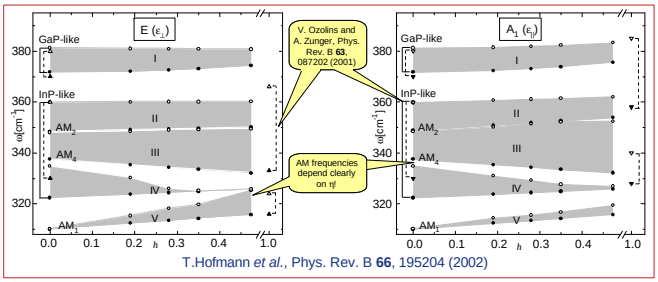
FIR-dielectric tensor



CuPt-ordering induced FIR birefringence

- Im(ε)- and Im(1/ε)-model dielectric function spectra parallel $e_\parallel$ and perpendicular $e_\perp$ to the direction of ordering
- TO- and AM-modes are local maxima of Im(ε) (vertical solid and dotted lines)
- LO- and AM-modes are local maxima of Im(1/ε) (vertical solid and dotted lines)

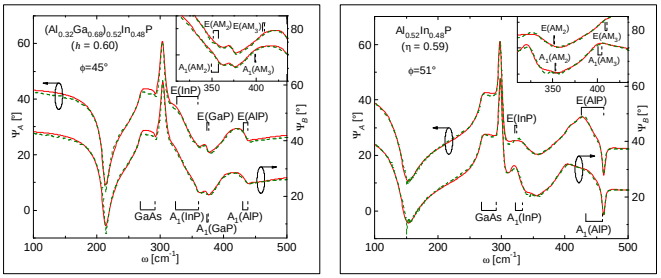
Phonon modes



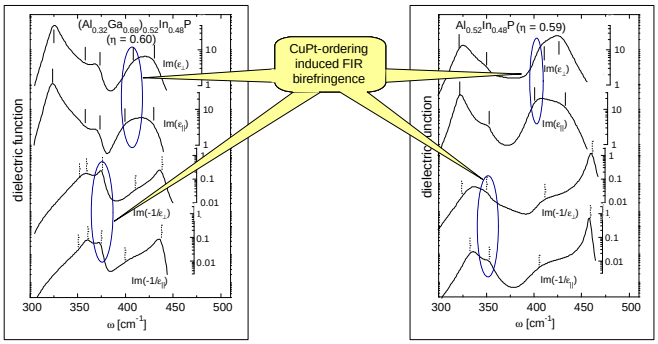
T.Hofmann *et al.*, Phys. Rev. B **66**, 195204 (2002)

$(Al_xGa_{1-x})_{0.52}In_{0.48}P$

FIR-SE analysis



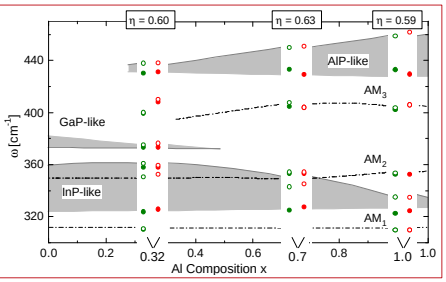
FIR-dielectric tensor



CuPt-ordering induced FIR birefringence

Phonon modes

- phonon modes of highly *disordered* AlGaInP show in addition to „GaP"-, „InP"-, and „AlP"-like modes alloy induced modes
  T.Hofmann *et al.*, Phys. Rev. B **64**,155206 (2001)
- depends on composition
- CuPt-ordering induced splitting of modes with E and A_1 symmetry
- degree of ordering:
  M.Schubert *et al.* (unpublished)



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