Temperature dependent dielectric function of $Al_{0.51}In_{0.49}P$ and $Ga_{0.51}In_{0.49}P$

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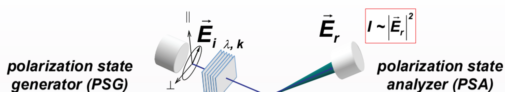
Our message

Optical in-situ monitoring and growth parameter control of $(Al_xGa_{1-x})InP$ requires precise knowledge of the optical properties of $(Al_xGa_{1-x})InP$ at growth temperatures!

In-situ spectroscopic ellipsometry is used to determine the dielectric function of $Al_{0.51}In_{0.49}P$ and $Ga_{0.51}In_{0.49}P$ in the temperature interval from room temperature to 500 °C.

We successfully employ Adachi's composite critical point model to describe the dielectric function of $Al_{0.51}In_{0.49}P$ and $Ga_{0.51}In_{0.49}P$ and determine the temperature dependence of critical point energies, amplitudes, and broadening parameters.

Experiment and model



$$I \sim |\vec{E}_r|^2$$

$$\rho = \frac{r_p}{r_s} \tan\Psi \exp(i\Delta)$$

Model dielectric funciton

E_0 critical point | E_1 critical point | Exciton | E_2 critical point

$$\varepsilon(E,T) = \varepsilon^{(0)}(E,T) + \varepsilon^{(1)}(E,T) + \varepsilon^{(1x)}(E,T) + \varepsilon^{(2)}(E,T)$$

$$\varepsilon^{(0)}(E) = A_0 E_0^{-1.5}\{\chi_0^{-2}[2-(1+\chi_0)^{0.5}]\}$$

$$\chi_j = \frac{(E+i\Gamma_j)}{E_j} \quad ; \quad Where\ j = 0,1$$

$$\varepsilon^{(1)} = -A_1 \chi_1^{-2} \ln(1-\chi_1^2)$$

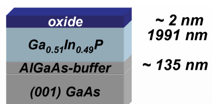
$$\varepsilon^{(1x)} = \frac{A_{1x}\exp(ip_{1x})}{E_1 - E - i\Gamma_{1x}\exp(-s_{1x}[E_1-E]^2)}$$

$$\varepsilon^{(2)} = \frac{A_2\exp(ip_2)}{1-\left(\frac{E}{E_2}\right)^2 - i\left(\frac{E}{E_2}\right)\left(\frac{\Gamma_2}{E_2}\right)\exp(-s_2[E-E_2]^2)}$$

- critical point contributions:
  - E_i – transition energy
  - Γ_i – broadening parameter
  - A_i – amplitude
- exciton contribution:
  - E_i – transition energy
  - Γ_i – broadening parameter
  - p_i – phase of the complex magnitude
  - A_i – amplitude

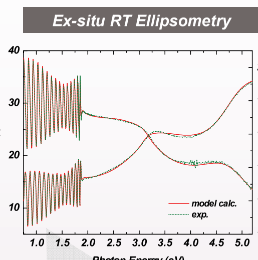
References: H. Thompkins and E. A. Irene (Eds.) Handbook of Ellipsometry, William Andrew Publishing, Highland Mills, 2004.
M. Schubert, J.A. Woollam, G. Leibiger, et al., J. Appl. Phys. 89, 2025 (1999).
S. Adachi, T. Kimura, and N. Suzuki, J. Appl. Phys. 74, 3435 (1993).

$Ga_{0.51}In_{0.49}P$



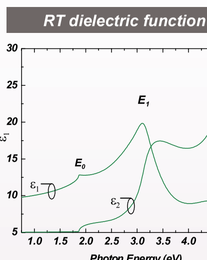
~ 2 nm	oxide layer
1991 nm	undoped $Ga_{0.51}In_{0.49}P$ epilayer
~ 135 nm	undoped AlGaAs buffer and substrate

Ex-situ RT Ellipsometry



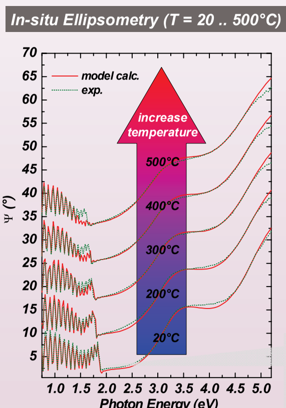
Fabry-Perot interferences in the transparent region of the GaInP film below the fundamental band gap.

RT dielectric function



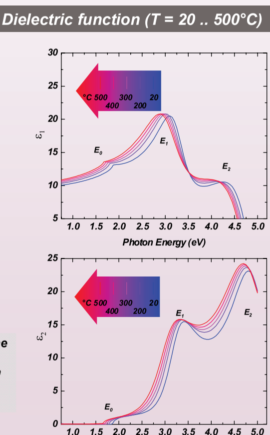
Best-fit model dielectric function for GaInP at room temperature.

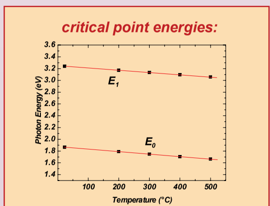
In-situ Ellipsometry (T = 20 .. 500°C)



Red-shift of the fundamental Band gap with increasing temperature.

Dielectric function (T = 20 .. 500°C)





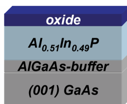
Best-fit model dielectric function for GaInP from room temperature to 500 °C.

Linear decrease of the critical point energies with increasing temperature:

E_0=1.866 - 4.3 10^{-4} T

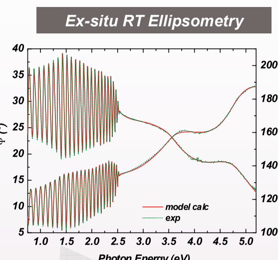
E_1=3.248 - 3.8 10^{-4} T

$Al_{0.51}In_{0.49}P$



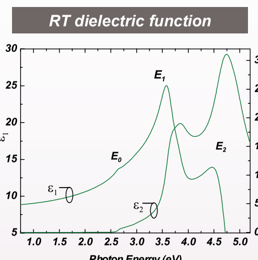
~ 3 nm	oxide layer
2060 nm	undoped $Al_{0.51}In_{0.49}P$ epilayer
~ 130 nm	undoped AlGaAs buffer and substrate

Ex-situ RT Ellipsometry



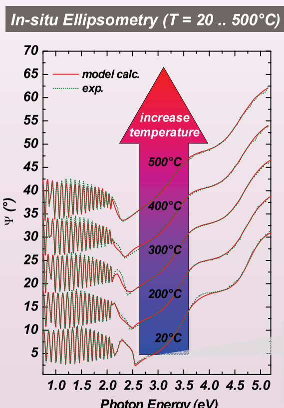
Fabry-Perot interferences in the transparent region of the AlInP film below the fundamental band gap.

RT dielectric function



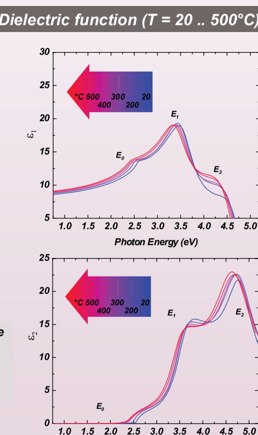
Best-fit model dielectric function for AlInP at room temperature.

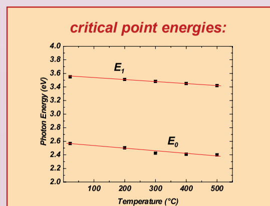
In-situ Ellipsometry (T = 20 .. 500°C)



Red-shift of the fundamental Band gap with increasing temperature.

Dielectric function (T = 20 .. 500°C)





Best-fit model dielectric function for AlInP from room temperature to 500 °C.

Linear decrease of the critical point energies with increasing temperature:

E_0=2.568 - 3.8 10^{-4} T

E_1=3.560 - 2.8 10^{-4} T

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