High Temperature Transport Properties of AlGaN/GaN Heterostructures

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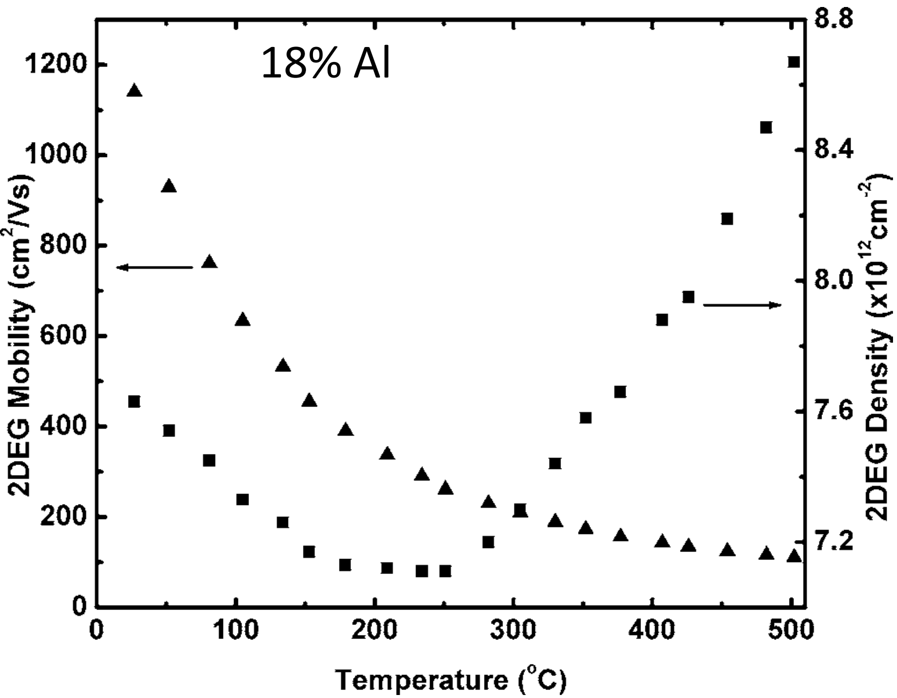
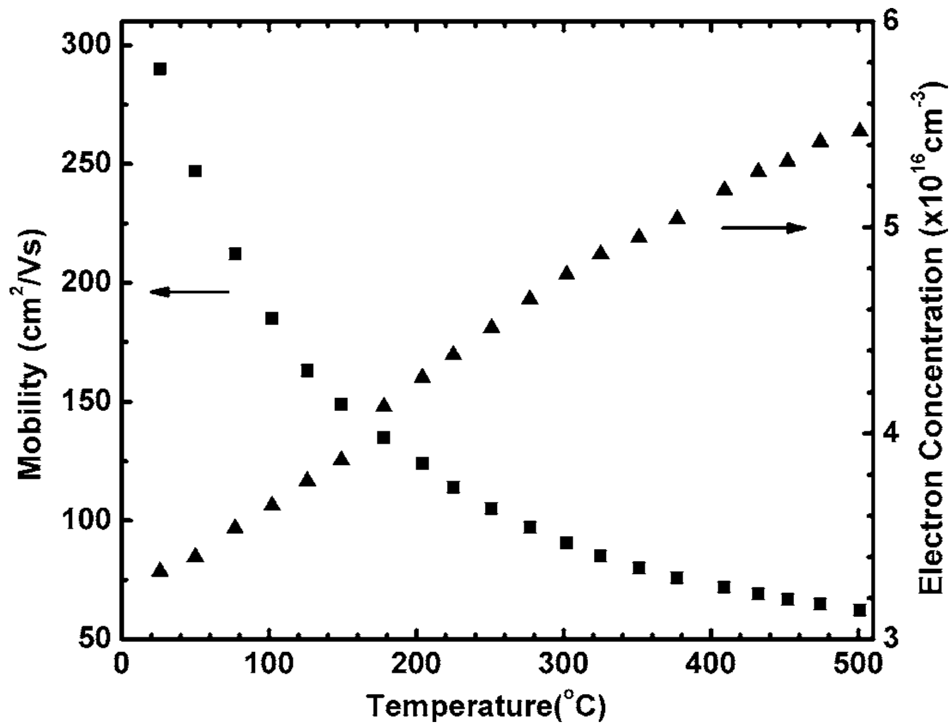
Outline

- Experimental and published theoretical data
- 1D Poisson Calculations
- Polar Optical Phonon Scattering Rate Calculation Method

Experimental 2DEG Mobility and Density vs. T





Unintentionally doped AlGaN and GaN

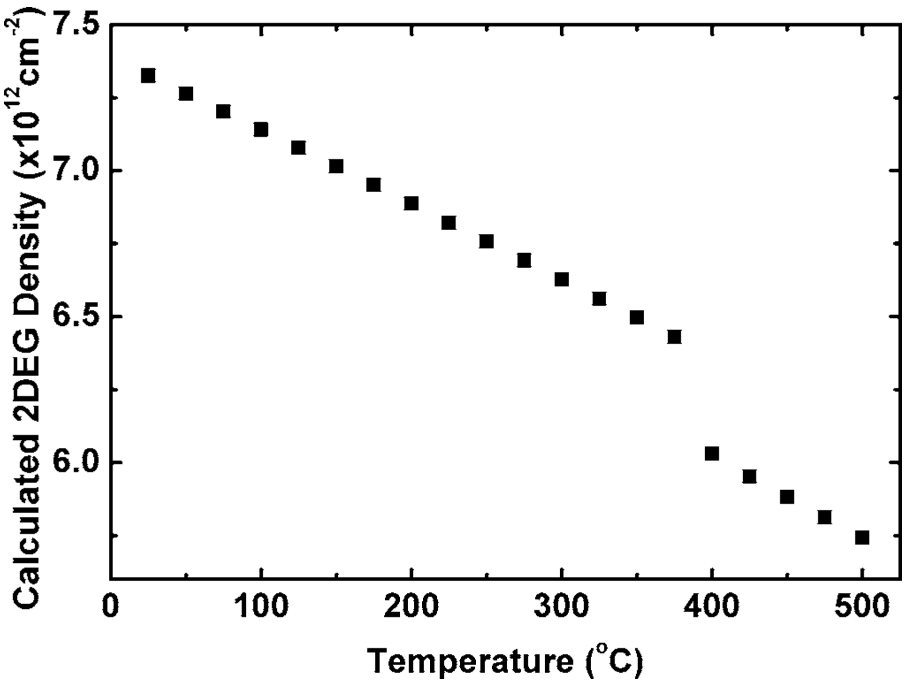
M.J. Wang et al. Appl. Phys. A 88, 715-718 (2007)

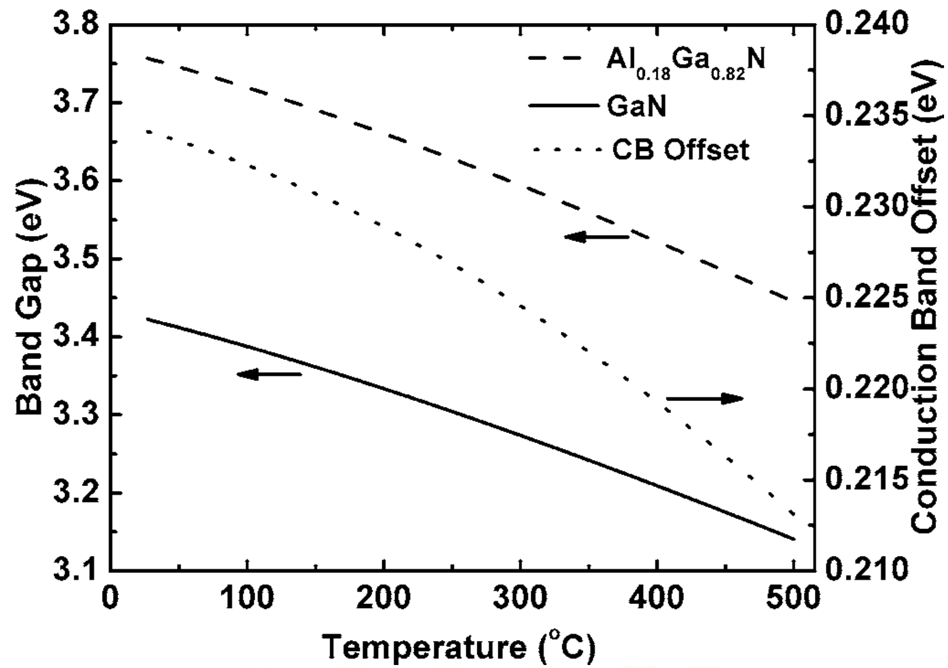
$$n_M \mu_M = n_{2DEG}\mu_{2DEG} + n_{GaN}\mu_{GaN}$$

$$T_{ionization} \approx \frac{E_c - E_D}{k} \ln\left(\frac{N_d}{N_c}\right)$$

E_d ~ 0.21 eV $T_{ionization}$ ~ 400 K

Theoretical 2DEG Density vs. T





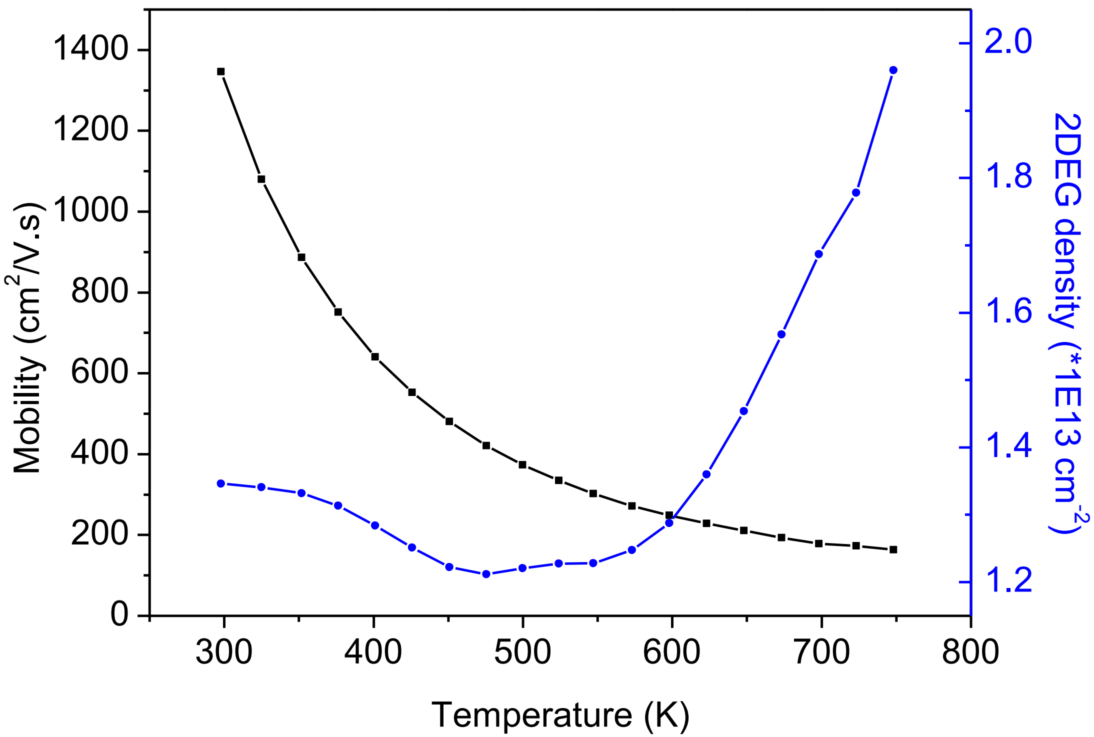
M.J. Wang et al. Appl. Phys. A 88, 715-718 (2007)

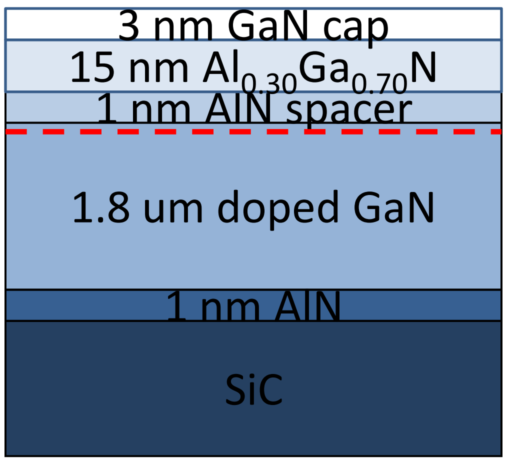
$$E_g(x, T) = (1-x)E_g(\mathrm{GaN})(T) + xE_g(\mathrm{AlN})(T) - bx(1-x),$$

$$E_g(T) = E_g(0) - \frac{\alpha T^2}{\beta + T}.$$

- CB offset assumed to 70% of total offset

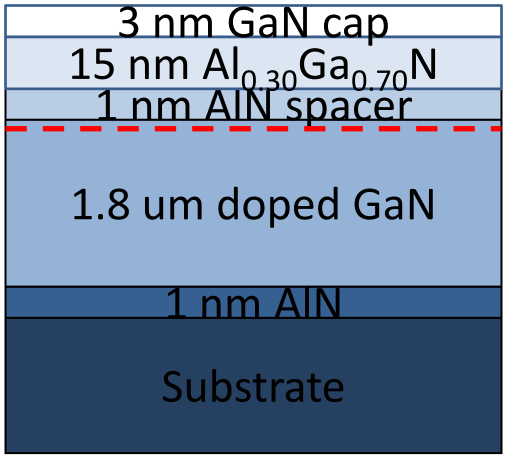
Ronghua's Data

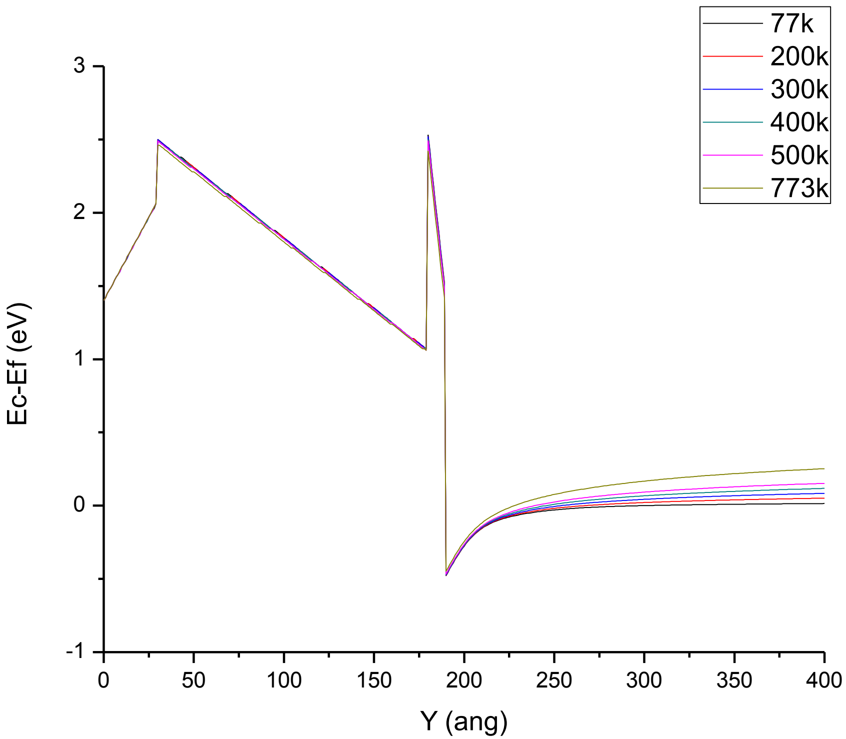


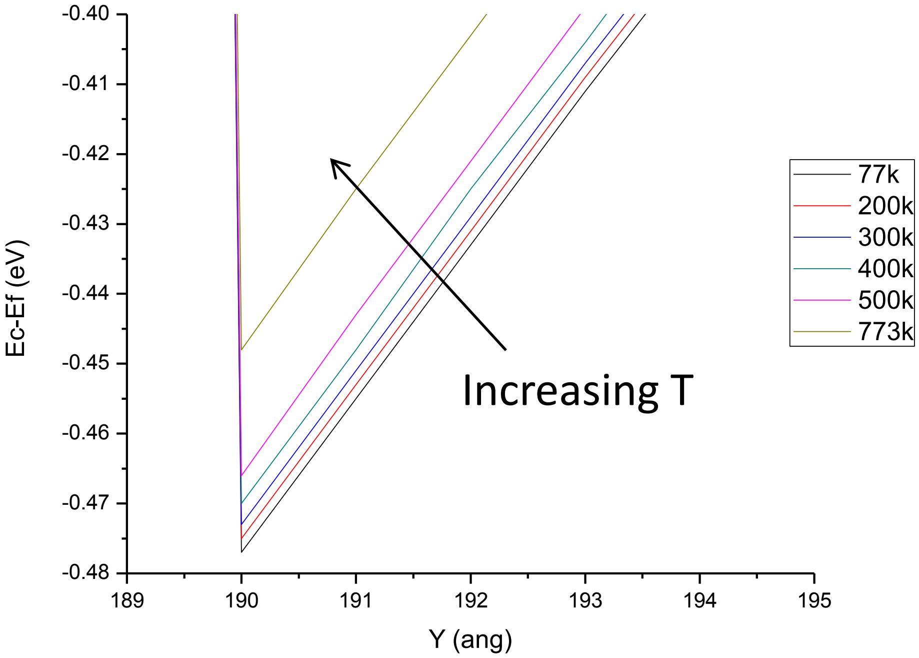


- Shows similar trend as previous data

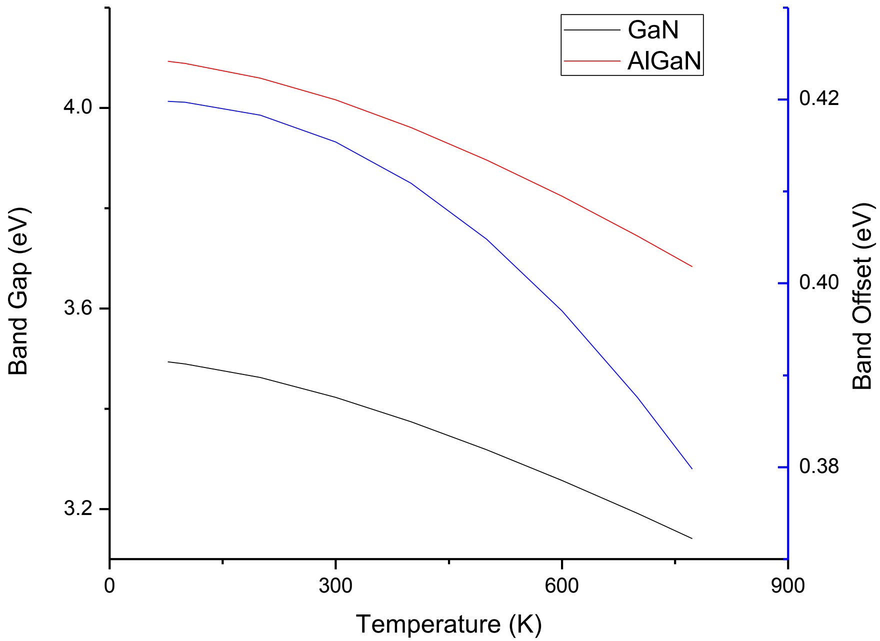
1D Poisson Calculations

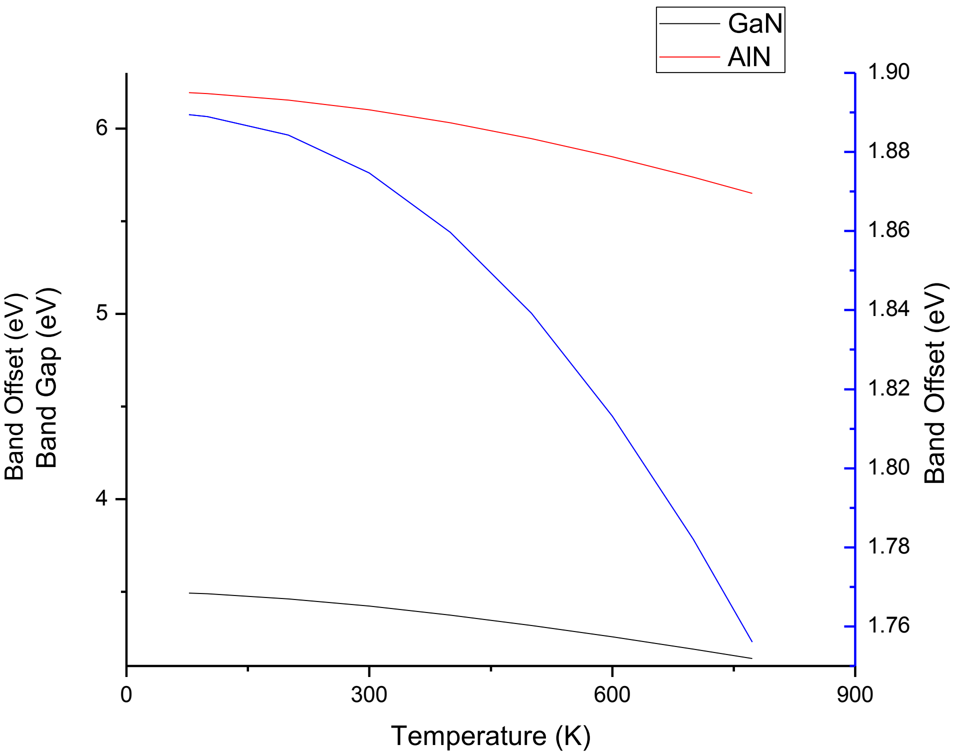




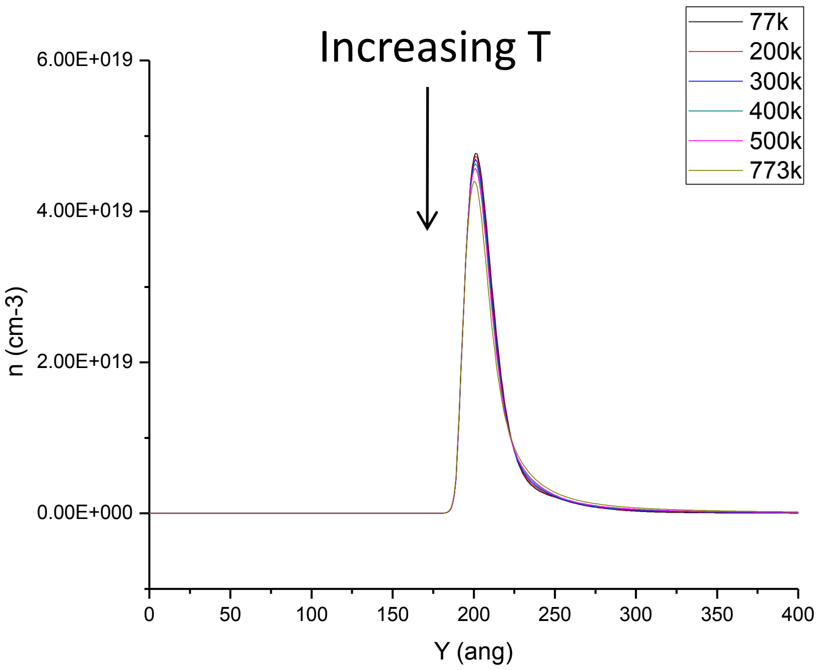


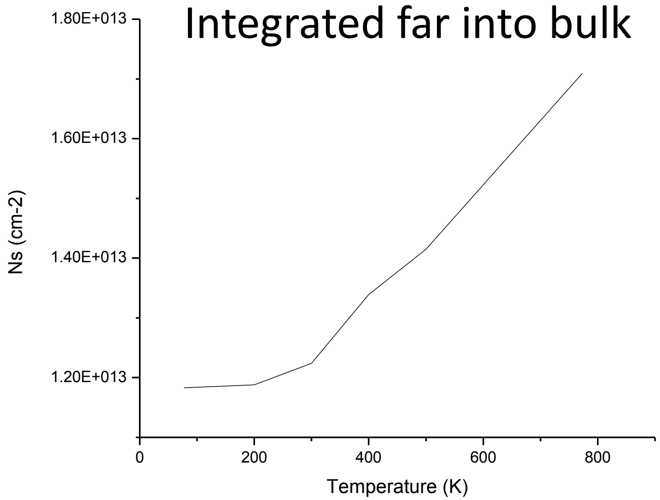
Temperature Dependence of Eg and CB Offset

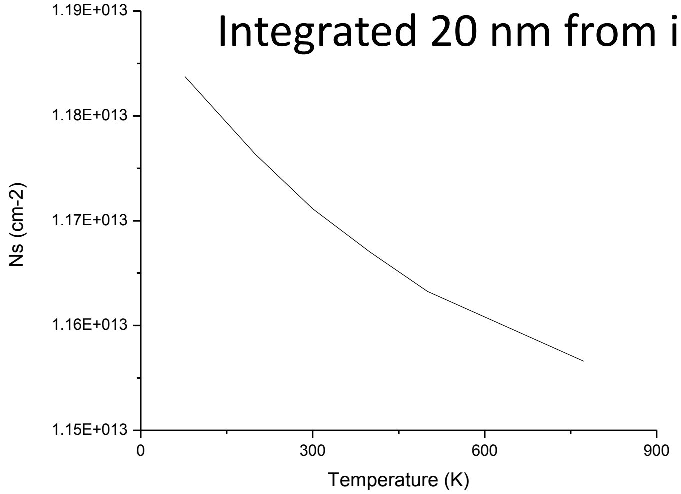




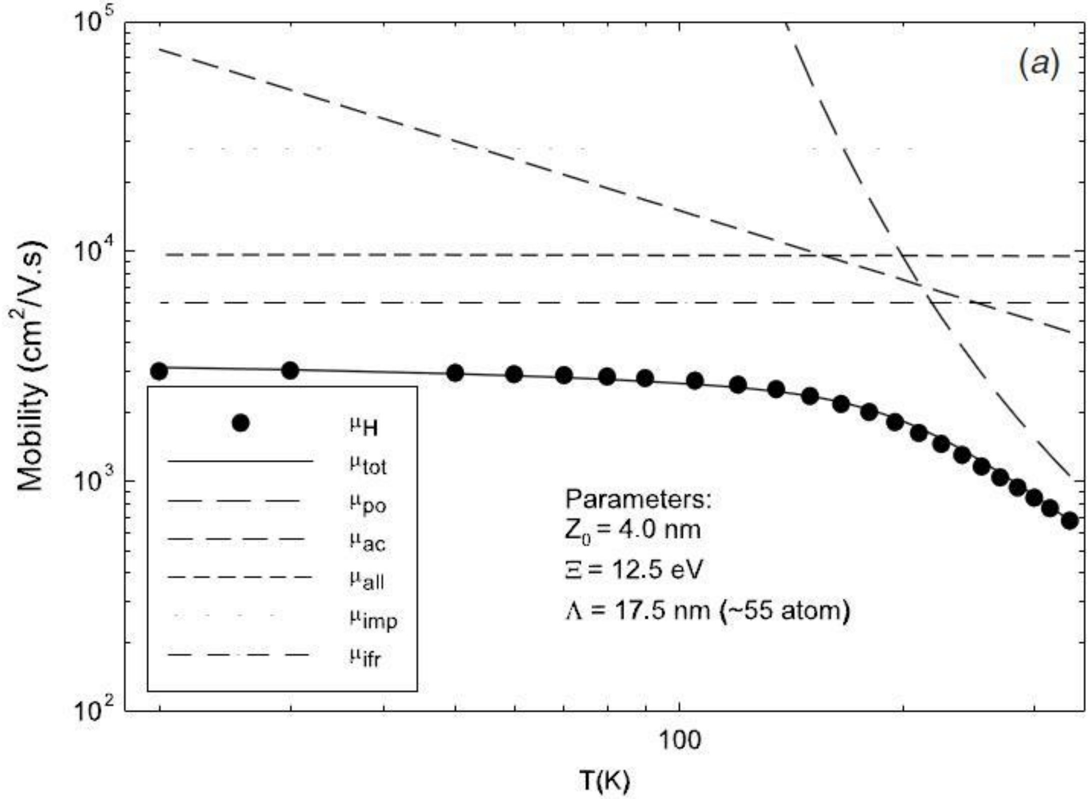
1D Poisson Calculations







Scattering Mechanisms



- POP scattering is dominate at high temperatures.

S B Lisesivdin et al. Semiconductor Science and Technology, 22 (2007) 543-548

Phonon Scattering Rate Calculation Procedure

$$H_{p'p} = \int_{-\infty}^{\infty} F_f^*(z) \frac{e^{-ip_{\parallel}^{'} \bullet \rho / \hbar}}{\sqrt{A}} (A_\beta K_\beta e^{\pm i\beta_{\parallel} \bullet \rho} e^{\pm i\beta_z z}) F_i(z) \frac{e^{ip_{\parallel} \bullet \rho / \hbar}}{\sqrt{A}} dz d\rho$$

$F_f(z)$: Envelope functions for quantum well
ħβ : difference in initial and final momentum states

$$A_\beta = \frac{\hbar}{2\rho\Omega\omega_\beta}(N_{\omega_\beta}) \qquad \left|K_\beta\right|^2 = \left(\frac{\rho q^2 \omega_0^2}{\beta^2 \kappa_0 \varepsilon_0}\right)\left(\frac{\kappa_0}{\kappa_\infty} - 1\right)$$

$$\frac{1}{\tau_{fi}} = \sum_{p_{\parallel}^{'}} \frac{2\pi}{\hbar} \{ \sum_{p_z^{'}} \left| I_{fi}(\beta_z) \right|^2 \left| K_\beta \right|^2 \left| A_\beta \right|^2 \} \delta_{p_{\parallel}^{'}, p_{\parallel} \pm \hbar\beta_{\parallel}} \delta(E^{'} - E \mp \hbar\omega)$$

Future Work

- Finish POP scattering rate calculation
- Calculate other scattering rates to confirm POP dominates