EE 362 Electronic, Magnetic, & Optical Properties of Materials
Quiz 6 (Spring 2024)

Name Key A

Instructions: Open book & notes. Place answers in indicated spaces. Show **all** work. Use 4-5 significant figures.

At 300 K, a section of gallium arsenide has been uniformly doped exclusively with acceptor atoms to a concentration of 5×10^{13} #/cm^3. First, find the majority & minority carrier concentrations (#/cm^3), majority & minority carrier mobilities (cm^2/V-s), and majority & minority diffusion coefficients (cm^2/s). Then, determine the ambipolar carrier mobility (cm^2/V-s) and diffusion coefficient (cm^2/s).

$N_a = 5\times10^{13}\ \#/cm^3$ From Table B.4, $n_i = 1.8\times10^{6}\ \#/cm^3$ @ 300K for GaAs

majority carriers $= p_o \simeq N_a = \underline{5\times10^{13}\ \#/cm^3}$ can confirm w/ (4.62)

(4.43) $n_o p_o = n_i^2 \Rightarrow n_o = \dfrac{(1.8\times10^6)^2}{5\times10^{13}} = \underline{0.0648\ \#/cm^3}$ minority carriers

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As $N_a = 5\times10^{13}\ \#/cm^3 < 10^{14}\ cm^{-3}$ on graph, use Table 5.1 to get mobilities

$\mu_n = \underline{8500\ cm^2/V\text{-}s}$ (minority)

$\mu_p = \underline{400\ cm^2/V\text{-}s}$ (majority)

Per Einstein relation (5.47)

$$\frac{D_n}{\mu_n} = \frac{D_p}{\mu_p} = \frac{k_B T}{e} = \frac{(8.617333\times10^{-5}\ eV/K)\,300K}{e} = 0.025852\ V$$

$D_n = 8500(0.025852) = \underline{219.742\ cm^2/s}$ (minority)

$D_p = 400(0.025852) = \underline{10.3408\ cm^2/s}$ (majority)

Since $p_o >> n_o$ (p-type)

(6.45) $D' = D_n = \underline{219.742\ \frac{cm^2}{s}}$ & (6.46) $\mu' = \mu_n = \underline{8500\ \frac{cm^2}{V\text{-}s}}$

p_o = majority carrier conc. = 5×10^{13} #/cm³ n_o = minority carrier conc. = 0.0648 #/cm³

majority carrier mobility = $\mu_p = 400$ cm²/V-s minority carrier mobility = $\mu_n = 8500$ cm²/V-s

majority diffusion coeff. = $D_p = 10.341$ cm²/s minority diffusion coeff. = $D_n = 219.742$ cm²/s

ambipolar carrier mobility = $\mu' = 8500$ cm²/s ambipolar diffusion coeff. = $D' = 219.742$ cm²/s

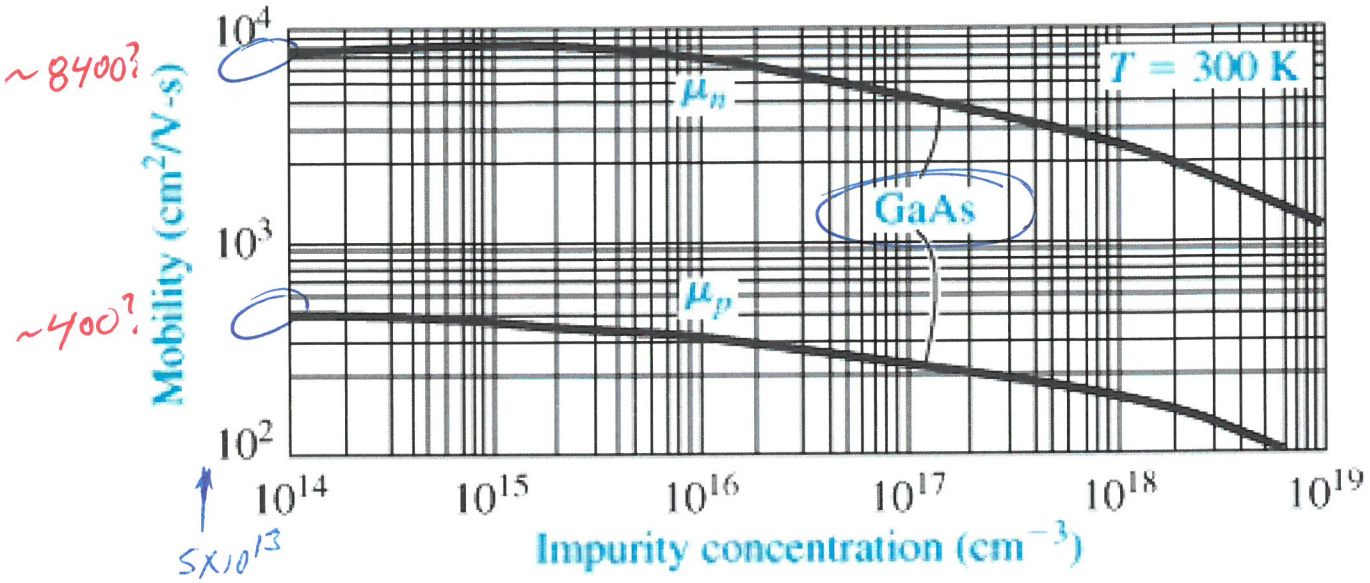
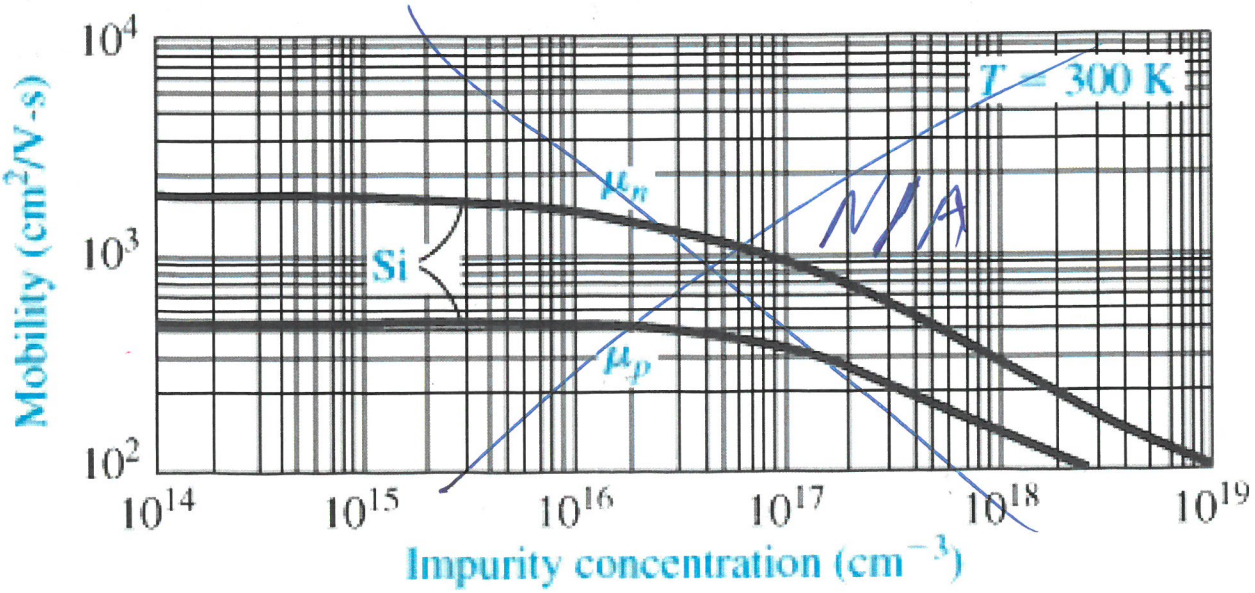


Table 5.1 | Typical mobility values at $T = 300$ K and low doping concentrations

use →

	μ_n (cm²/V-s)	μ_p (cm²/V-s)
Silicon	1350	480
Gallium arsenide	8500	400
Germanium	3900	1900



EE 362 Electronic, Magnetic, & Optical Properties of Materials
Quiz 6 (Spring 2024)

Name Key C

Instructions: Open book & notes. Place answers in indicated spaces. Show **all** work. Use 4-5 significant figures.

At 300 K, a section of silicon has been uniformly doped exclusively with donor atoms to a concentration of 2×10^{14} #/cm^3. First, find the majority & minority carrier concentrations (#/cm^3), majority & minority carrier mobilities (cm^2/V-s), and majority & minority diffusion coefficients (cm^2/s). Then , determine the ambipolar carrier mobility (cm^2/V-s) and diffusion coefficient (cm^2/s).

$N_d = 2\times10^{14}\ \#/cm^3$ From Table B.4, $n_i = 1.5\times10^{10}\ \#/cm^3$ @ 300K for Si

majority carriers $= n_0 = N_d = \underline{2\times10^{14}\ \#/cm^3}$ can confirm w/ (4.60)

(4.43) $n_0 p_0 = n_i^2 \Rightarrow p_0 = \dfrac{(1.5\times10^{10})^2}{2\times10^{14}} = \underline{1.125\times10^{6}\ \#/cm^3}$ minority carriers

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use either Si graph or Table 5.1 to get mobilities $\underline{\mu_n = 1350\ cm^2/V\text{-}s}$ (majority)

$\underline{\mu_p = 480\ cm^2/V\text{-}s}$ (minority)

Per Einstein relation (5.47)

$D_n/\mu_n = D_p/\mu_p = \dfrac{k_B T}{e} = 8.617333\times10^{-5}(300) = 0.025852\ V$

$D_n = 1350(0.025852) = \underline{34.9002\ cm^2/s}$ (majority)

$D_p = 480(0.025852) = \underline{12.40896\ cm^2/s}$ (minority)

Since $n_0 >> p_0$ (n-type)

(6.47) $D' = D_p = \underline{12.409\ \frac{cm^2}{s}}$ and (6.48) $\mu' = -\mu_p = -480\ \frac{cm^2}{V\text{-}s}$

n_0 = majority carrier conc. = 2×10^{14} #/cm³ p_0 = minority carrier conc. = 1.125×10^{6} #/cm³

majority carrier mobility = $\mu_n = 1350$ cm²/V-s minority carrier mobility = $\mu_p = 480$ cm²/V-s

majority diffusion coeff. = $D_n = 34.9$ cm²/s minority diffusion coeff. = $D_p = 12.409$ cm²/s

μ' = ambipolar carrier mobility = -480 cm²/V-s D' = ambipolar diffusion coeff. = 12.409 cm²/s

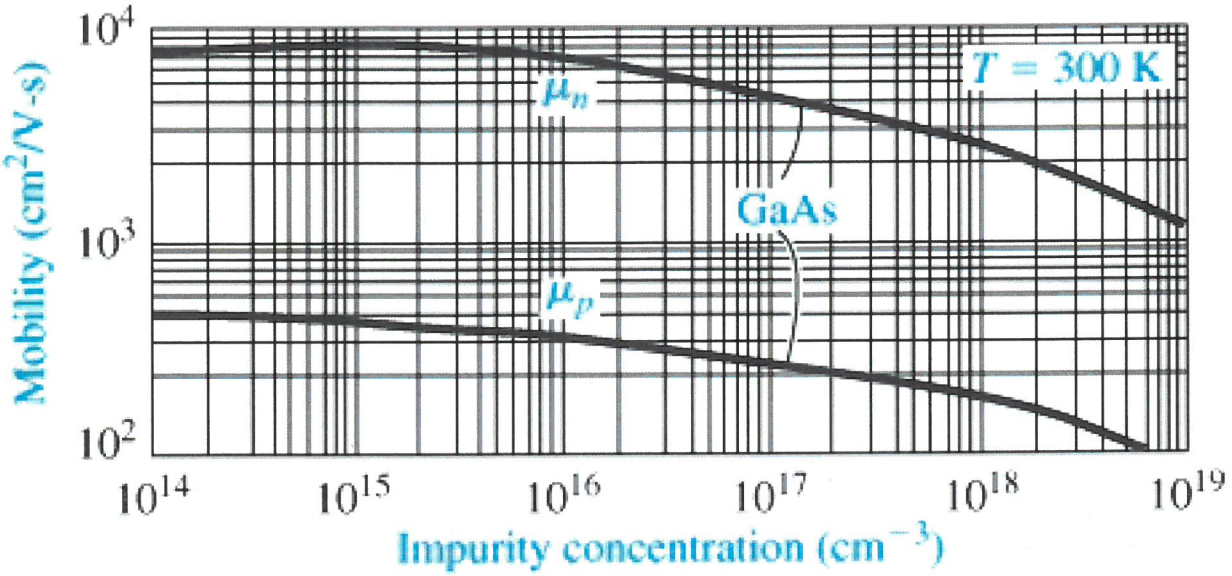

Table 5.1 | Typical mobility values at $T = 300$ K and low doping concentrations

use →

	μ_n (cm²/V-s)	μ_p (cm²/V-s)
Silicon	1350	480
Gallium arsenide	8500	400
Germanium	3900	1900

~1500?

~410?