# EE 362 Electronic, Magnetic, & Optical Properties of Materials
# Quiz 5 (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 germanium is being used as resistive trace. It has been doped only with acceptor atoms to a concentration of $6 \times 10^{16}$ #/cm$^3$. Determine the intrinsic carrier concentration (#/cm$^3$), majority carrier type, majority carrier concentration (#/cm$^3$), majority carrier mobility (cm$^2$/V-s), conductivity (S/cm), and resistivity (Ω-cm) of the doped germanium. Find the required width (μm) of the resistive trace to implement a resistance of 160 Ω if the trace is 50 μm long and the doping penetrates to a depth of 8 μm.

## MathCad

**Given** $e := 1.602176634 \cdot 10^{-19}$ C $\quad Nd := 0$

$Na := 6 \cdot 10^{16}$ cm$^{-3}$ $\quad L := 50 \cdot 10^{-6}$ m $\quad d := 8 \cdot 10^{-6}$ m $\quad R := 160$ Ω

**From Table B.4, the intrinsic carrier concentration-** $ni := 2.4 \cdot 10^{13}$ cm$^{-3}$

**(4.62), $p \sim N_a >> n_i$ implies the majority charges are holes.**

$$p := \frac{Na - Nd}{2} + \sqrt{\left(\frac{Na - Nd}{2}\right)^2 + ni^2} \qquad p = 6.000001 \times 10^{16} \text{ cm}^{-3}$$

**From Fig. 5.3 (Ge), the hole mobility is** $\mu p := 1000$ cm$^2$/V-s

**(5.23)** $\sigma\_Scm := e \cdot \mu p \cdot p$ $\quad \sigma\_Scm = 9.61306$ S/cm

$\sigma := \sigma\_Scm \cdot 100$ $\quad \sigma = 961.306134$ S/m

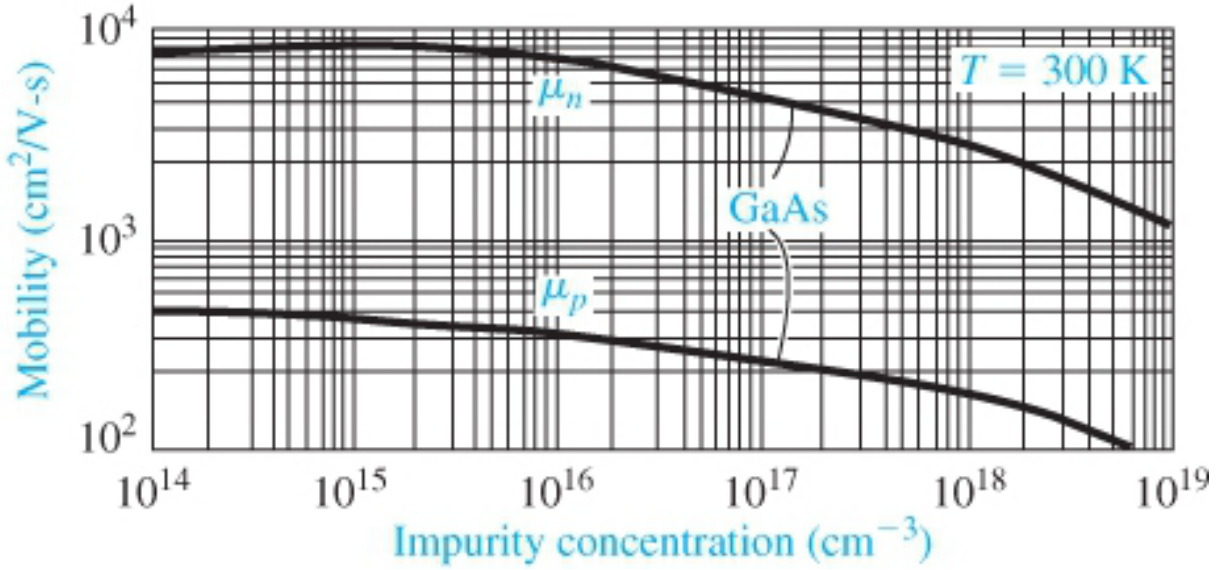
**(5.20)** $\rho := \frac{1}{\sigma\_Scm}$ $\quad \rho = 0.10403$ Ω-cm

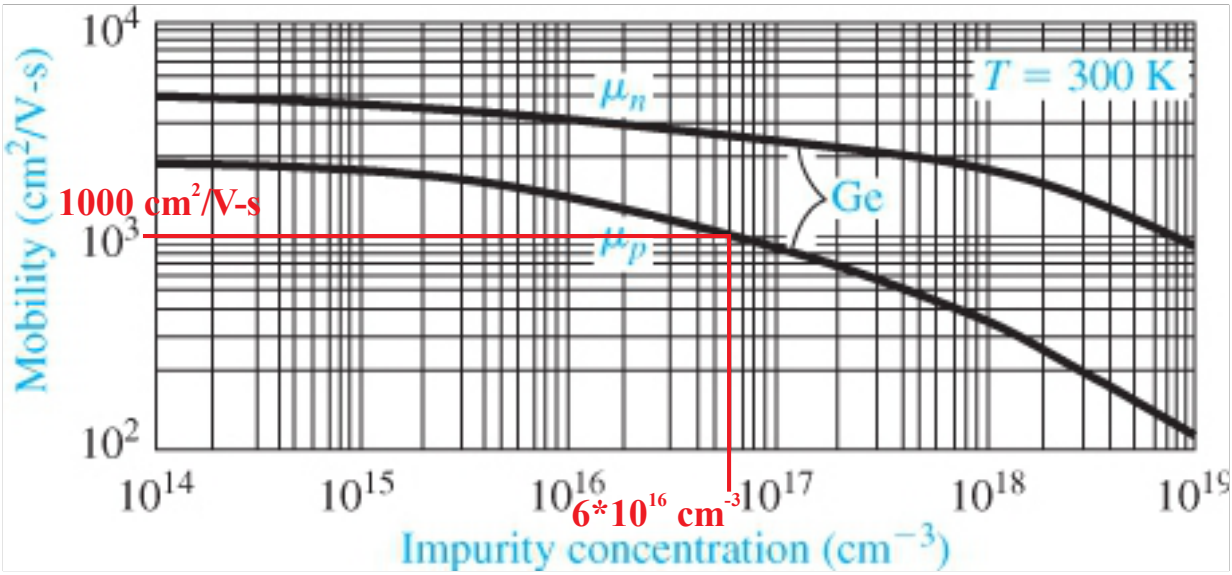
**(5.22b)** $W := \frac{L}{\sigma \cdot d \cdot R}$ $\quad W = 4.063482 \times 10^{-5}$ m

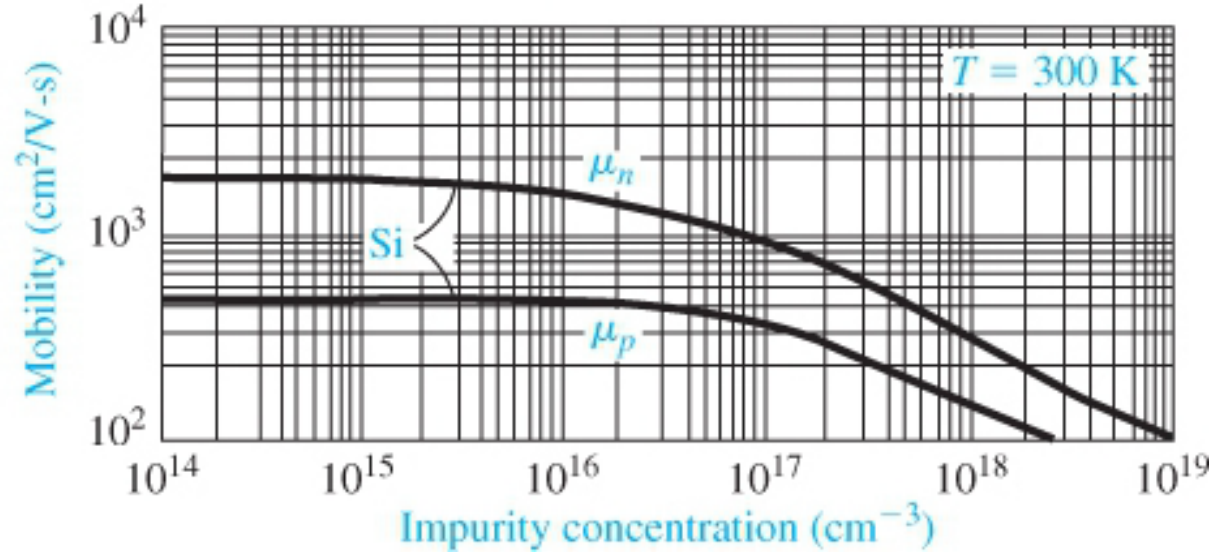
intrinsic carrier conc. = **$2.4 \times 10^{13}$ #/cm$^3$** majority carrier type: **holes** or electrons (circle)

majority carrier conc. = **$6 \times 10^{16}$ #/cm$^3$** majority carrier mobility = **$\mu_p$ = 1000 cm$^2$/V-s**

conductivity = **9.6131 S/cm** resistivity = **0.10403 Ω-cm** width = **40.635 μm**


Mobility ($cm^2$/V-s)
$10^4$
$10^3$
$10^2$
$\mu_n$
$\mu_p$
GaAs
$T = 300$ K
$10^{14}$ $10^{15}$ $10^{16}$ $10^{17}$ $10^{18}$ $10^{19}$
Impurity concentration ($cm^{-3}$)


Mobility ($cm^2$/V-s)
$10^4$
$10^3$
$10^2$
1000 $cm^2$/V-s
$\mu_n$
$\mu_p$
Ge
$T = 300$ K
$10^{14}$ $10^{15}$ $10^{16}$ $10^{17}$ $10^{18}$ $10^{19}$
6*$10^{16}$ $cm^{-3}$
Impurity concentration ($cm^{-3}$)


Mobility ($cm^2$/V-s)
$10^4$
$10^3$
$10^2$
$\mu_n$
$\mu_p$
Si
$T = 300$ K
$10^{14}$ $10^{15}$ $10^{16}$ $10^{17}$ $10^{18}$ $10^{19}$
Impurity concentration ($cm^{-3}$)

# EE 362 Electronic, Magnetic, & Optical Properties of Materials
# Quiz 5 (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 germanium is being used as resistive trace. It has been doped only with acceptor atoms to a concentration of $9 \times 10^{16}$ #/cm$^3$. Determine the intrinsic carrier concentration (#/cm$^3$), majority carrier type, majority carrier concentration (#/cm$^3$), majority carrier mobility (cm$^2$/V-s), conductivity (S/cm), and resistivity (Ω-cm) of the doped germanium. Find the required width (μm) of the resistive trace to implement a resistance of 120 Ω if the trace is 40 μm long and the doping penetrates to a depth of 9 μm.

## MathCad

**Given** $e := 1.602176634 \cdot 10^{-19}$ C $\quad Nd := 0$

$Na := 9 \cdot 10^{16}$ cm$^{-3}$ $\quad L := 40 \cdot 10^{-6}$ m $\quad d := 9 \cdot 10^{-6}$ m $\quad R := 120$ Ω

**From Table B.4, the intrinsic carrier concentration-** $ni := 2.4 \cdot 10^{13}$ cm$^{-3}$

**(4.62), $p \sim N_a >> n_i$ implies the majority charges are holes.**

$$p := \frac{Na - Nd}{2} + \sqrt{\left(\frac{Na - Nd}{2}\right)^2 + ni^2}$$

$p = 9.000001 \times 10^{16}$ cm$^{-3}$

**From Fig. 5.3 (Ge), the hole mobility is** $\mu p := 900$ cm$^2$/V-s

**(5.23)** $\sigma\_Scm := e \cdot \mu p \cdot p$ $\quad \sigma\_Scm = 12.97763$ S/cm

$\sigma := \sigma\_Scm \cdot 100$ $\quad \sigma = 1297.763$ S/m

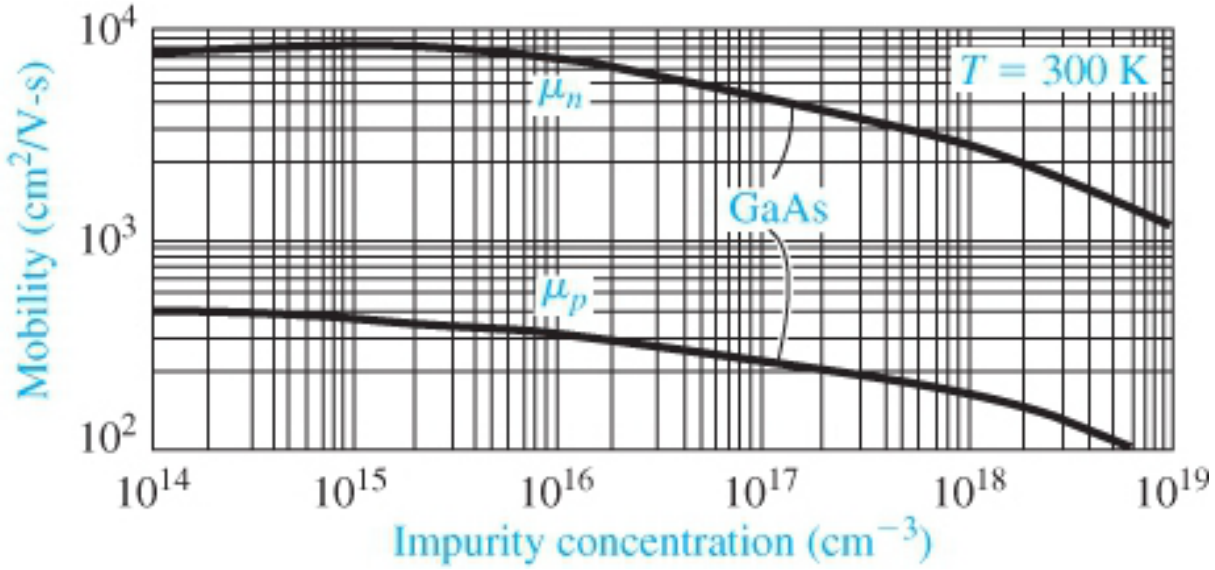
**(5.20)** $\rho := \frac{1}{\sigma\_Scm}$ $\quad \rho = 0.077056$ Ω-cm

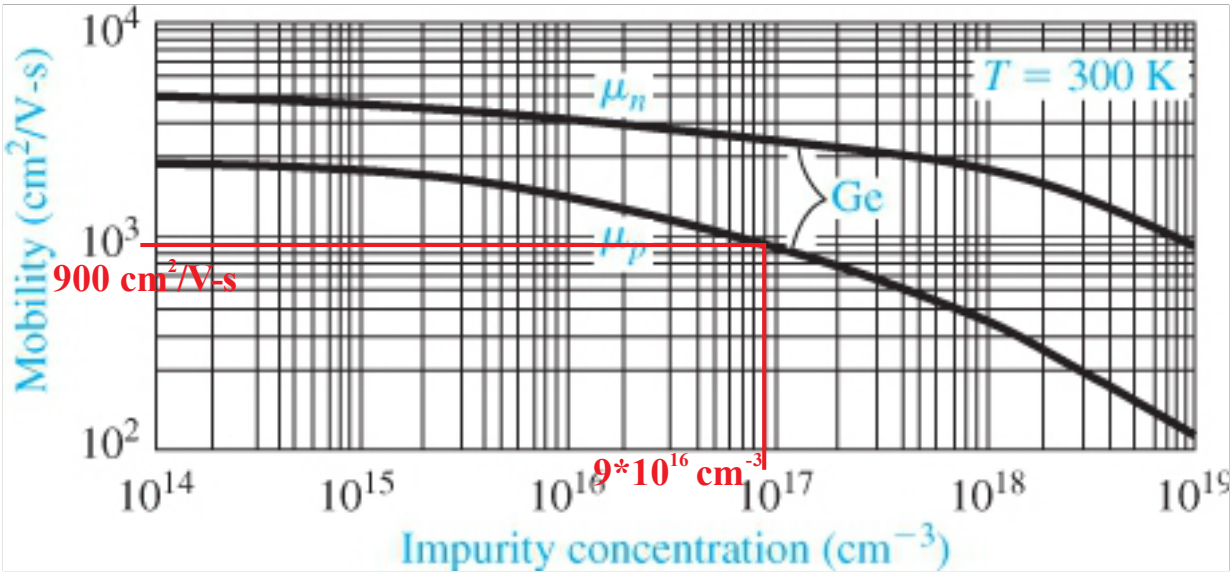
**(5.22b)** $W := \frac{L}{\sigma \cdot d \cdot R}$ $\quad W = 2.853913 \times 10^{-5}$ m

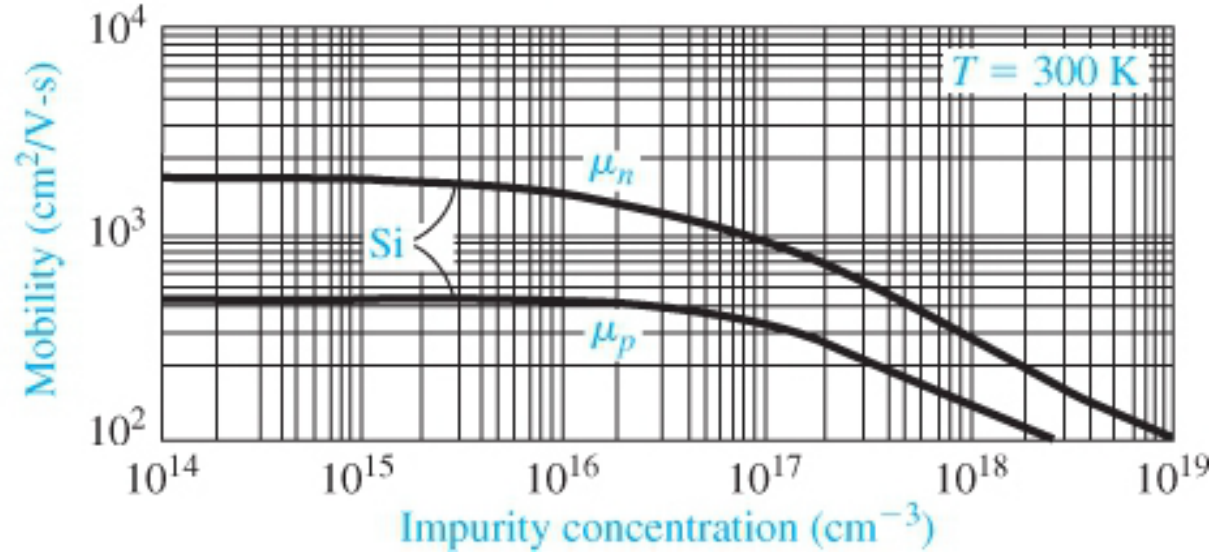
intrinsic carrier conc. = **$2.4 \times 10^{13}$ #/cm$^3$** majority carrier type: **holes** or electrons (circle)

majority carrier conc. = **$9 \times 10^{16}$ #/cm$^3$** majority carrier mobility = **$\mu_p = 900$ cm$^2$/V-s**

conductivity = **12.9776 S/cm** resistivity = **0.077056 Ω-cm** width = **28.539 μm**


Mobility (cm²/V-s)
10⁴
10³
10²
T = 300 K
μn
μp
GaAs
10¹⁴
10¹⁵
10¹⁶
10¹⁷
10¹⁸
10¹⁹
Impurity concentration (cm⁻³)


Mobility (cm²/V-s)
10⁴
10³
10²
T = 300 K
μn
μp
Ge
900 cm²/V-s
9*10¹⁶ cm⁻³
10¹⁴
10¹⁵
10¹⁶
10¹⁷
10¹⁸
10¹⁹
Impurity concentration (cm⁻³)


Mobility (cm²/V-s)
10⁴
10³
10²
T = 300 K
μn
μp
Si
10¹⁴
10¹⁵
10¹⁶
10¹⁷
10¹⁸
10¹⁹
Impurity concentration (cm⁻³)