1 impurity ; phonon (atomic vibration) 5'

concentration of impurity ↑, mobility ↓

temperature ↑, vibration ↑, mobility ↓ 5'

2 a) Assuming complete ionization at 300K

$n_0 \approx N_d = 10^{16}\ cm^{-3}$

$p_0 = \frac{n_i^2}{n_0} = 3.24 \times 10^{-4}\ cm^{-3}$ 5'

b) $\rho = n_0 q \mu_n E + p_0 q \mu_p E$

$= 10^{22} \cdot 1.6\times10^{-19} \cdot 750 \cdot 10^{-4} \cdot 10^{3} + 3.24\times10^{2} \cdot 1.6\times10^{-19} \cdot 310 \cdot 10^{-4} \cdot 10^{3}$

$= 1.2\times10^{6}\ A/m^2$ 5'

3 a) ✓ 10'

b) both

c) ✓

d) ✓

e) ✓

f) ✓

g) X

4 There are two main steps in SRH recombination

first an electron/hole is captured in trap state

then recombination happens

In this case, energy is likely to be released as thermal energy

Radiative recombination: electron and hole directly recombine, 5'

energy is likely to be released as photon, therefore radiative

Both contribute to the excess carrier lifetime, RSH is more likely to contribute more significantly in Si 5'

5 $D_p \frac{\partial^2 \delta p}{\partial x^2} - \frac{\delta p}{\tau_p} = 0$

a)

$\delta p = A e^{-x/\sqrt{D_p\tau_p}} + B e^{x/\sqrt{D_p\tau_p}}$ $B=0$ $L_p = \sqrt{D_p\tau_p} = 3.162\times10^{-5}\ m$

$\delta p = 10^{15} e^{-3.16\times10^{4} x}\ cm^{-3}$ 10'

b) $J = -qD_p \frac{d\delta p}{dx} = -1.6\times10^{-19} \cdot 10 \cdot 10^{-4} \cdot (-3.16\times10^{4}) \cdot 10^{21} \cdot e^{-3.16\cdot10^{4} \cdot 10^{-5}}$

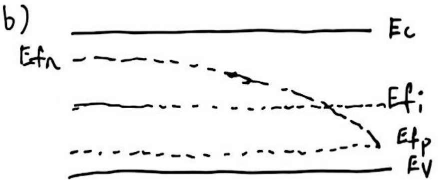
$= 3.69\times10^{3}\ A/m^2$ $\xrightarrow{J}$ 10'

6

a) $D_n = \mu_n \cdot \frac{kT}{q} = 1.295\times10^{-3}\ m^2 \cdot s^{-1}$

$J = qD_n \frac{dn}{dx} = 1.6\times10^{-19} \cdot 1.295\times10^{-3} \cdot \frac{10^{20} \cdot 10^{6}}{5\times10^{-6}} = 4.14\times10^{9}\ A/m^2$ $\xleftarrow{J}$ 10'

b)



10'

7

a) $g = \frac{\Delta p}{\tau_p}$

$\Delta p = g\tau_p = 10^{14}\,cm^{-3}$

$n_i = \sqrt{N_cN_v \exp(-E_g/kT)} = \sqrt{2.8\times10^{19}\cdot 1.04\times10^{19}\cdot(\frac{450}{300})^3\cdot \exp(-1.12/(0.0259\cdot\frac{450}{300}))} = 1.72\times10^{13}\,cm^{-3}$

$n \approx 10^{16}\,cm^{-3}$

$p \approx 10^{14}\,cm^{-3}$

$E_{fn} - E_{fi} = kT\ln\frac{n}{n_i} = 0.2477\,eV$ 5'

$E_{fi} - E_{fp} = kT\ln\frac{p}{n_i} = 0.0684\,eV$ 5'

b) $\Delta\sigma = \Delta n q\mu_n + \Delta p q\mu_p$

$= \Delta n\cdot q\, D_n\cdot\frac{q}{kT} + \Delta p\, q\cdot D_p\frac{q}{kT}$

$= 10^{20}\cdot 1.6\times10^{-19}\cdot 48\cdot 10^{-4}\,\frac{1}{0.0259\cdot\frac{450}{300}}$

$= 1.98\,(\Omega m)^{-1}$ 10'