# 中原大學97學年度碩士班入學考試

4月13日 16:00~17:30 電子工程學系固態組(甲組)

誠實是我們珍視的美德，
我們喜愛「拒絕作弊，堅守正直」的你！

科目：半導體基礎概論



■可使用計算機，惟僅限不具可程式及多重記憶者　□不可使用計算機

| | |
|---|---|
| Boltzmann's constant | $k = 1.38 \times 10^{-23}$ J/K $= 8.62 \times 10^{-5}$ eV/K |
| Electronic charge (magnitude) | $e = 1.6 \times 10^{-19}$ C |
| Free electron rest mass | $m = 9.11 \times 10^{-31}$ kg |
| Permeability of free space | $\mu_0 = 4\pi \times 10^{-7}$ H/m |
| Permittivity of free space | $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m |
| Planck's constant | $h = 6.625 \times 10^{-34}$ J-s $= 4.135 \times 10^{-15}$ eV-s |
| Speed of light in vacuum | $c = 3 \times 10^{8}$ m/s |
| Thermal voltage (T=300K) | Vt = KT/e = 0.026 Volt |

| **Property** (T=300K) | **Si** | **GaAs** | **Ge** |
|---|---|---|---|
| Atoms ($cm^{-3}$) | $5 \times 10^{22}$ | $4.42 \times 10^{22}$ | $4.42 \times 10^{22}$ |
| Atomic weight | 28.09 | 144.63 | 72.60 |
| Density ($g/cm^3$) | 2.33 | 5.32 | 5.33 |
| Lattice constant (Å) | 5.43 | 5.65 | 5.65 |
| Melting point (℃) | 1415 | 1238 | 937 |
| Dielectric constant | 11.7 | 13.1 | 16.0 |
| Bandgap energy (eV) | 1.12 | 1.42 | 0.66 |
| Electron affinity, $\chi$ (volts) | 4.01 | 4.07 | 4.13 |
| Effective density of states in conduction band, Nc ($cm^{-3}$) | $2.8 \times 10^{19}$ | $4.7 \times 10^{17}$ | $1.04 \times 10^{19}$ |
| Effective density of states in valence band, Nv ($cm^{-3}$) | $1.04 \times 10^{19}$ | $7.0 \times 10^{18}$ | $6.0 \times 10^{18}$ |
| Intrinsic carrier concentration ($cm^{-3}$) | $1.5 \times 10^{10}$ | $1.8 \times 10^{6}$ | $2.4 \times 10^{13}$ |
| Mobility ($cm^2$/V-s) | | | |
| Electron, $\mu n$ | 1350 | 8500 | 3900 |
| Hole, $\mu p$ | 480 | 400 | 1900 |

| **Property** (T=300K) | **SiO2** | **Si3N4** |
|---|---|---|
| Atomic or molecular density($cm^{-3}$) | $2.2 \times 10^{22}$ | $1.48 \times 10^{22}$ |
| Density($g\text{-}cm^{-3}$) | 2.2 | 3.4 |
| Energy gap | 9 eV | 4.7 eV |
| Dielectric constant | 3.9 | 7.5 |

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科目：半導體基礎概論　　（共 2 頁第 2 頁）

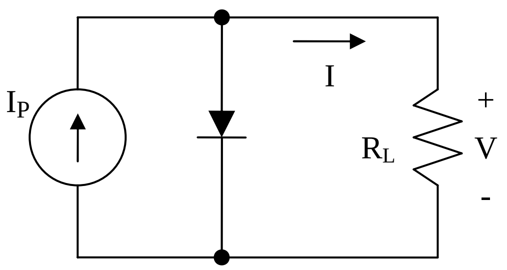
**You may use the above constants and properties if necessary. All questions are presumed at room temperature if not specified.**

1. An intrinsic germanium (Ge) is doped by $10^{15}$ $cm^{-3}$ donor impurity. (1) Find out its Fermi energy level and use an energy band diagram to indicate the Fermi energy level at room temperature. (2) Discuss the changes of its carrier concentration at temperatures from 10K to 500K. (3) Are there any electrical property and device application in which germanium performs better than silicon (Si) does? (4) Why do the modern IC industries prefer silicon other than germanium? (20%)

2. An intrinsic silicon is first doped by $10^{14}$ $cm^{-3}$ arsenic. (1) Find out its bulk resistivity at room temperature. (2) By further doping $5 \times 10^{14}$ $cm^{-3}$ boron to compensate the above arsenic-doped silicon, what is the bulk resistivity at room temperature? (3) Discuss the changes of its resistivity at temperatures from 10K to 500K. (4) Why do the modern IC industries use boron, arsenic and phosphorous more than other impurity elements for doping silicon-based devices? (20%)

3. A $n^+$-p diode, i.e. one-sided junction diode, is formed by having $10^{15}$ $cm^{-3}$ boron in the lightly doped silicon region. (1) Find out its built-in potential at room temperature. (2) Find out its depletion capacitance per unit area under 5V reverse bias. (3) Find out the maximum electric field under 5V reverse bias. (4) By further increasing the reverse bias, will this diode reach its maximum depletion width? Explain your prediction. (20%)

4. Considering an ideal p-n diode for solar cell applications, a photo current $I_P$ is generated under illumination. The equivalent circuit with load $R_L$ is shown in the following figure. (1) Find out the theoretical output power in the load. You may assume necessary diode parameters. (2) What is the maximum output power? (20%)




5. For a MOS capacitor, its silicon dioxide ($SiO_2$) thickness is 10 nm and its substrate is $10^{15}$ $cm^{-3}$ boron-doped silicon, (1) Sketch its theoretical energy band diagrams biased at accumulation, depletion and inversion modes. (2) Find out its capacitance per unit area under the accumulation mode. (3) Find out its maximum depletion width at the inversion mode. (4) What factors will be considered to determine its flat band voltage ($V_{FB}$)? (20%)