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End-Semester Question Paper – IC Fabrication Technology (MEL G 611)

Date: 16-12-2022 **Time: 14:00 hours to 17:00 hours**

Closed Book **Full-Marks: 40**

Use the Tables (wherever values are not given in the question) given below suitably for solving the problems

1. **Give a line diagram of a conventional molecular beam epitaxy and mark different portions clearly.**

   Calculate the mean free path (in m) of air-molecule (diameter = 3.7$\dot{A}$) at room temperature and at a pressure of 10^{-4} Pa using the formula using rigorous derivation. No derivation needed.

   Assume an effusion oven geometry of area A = 7 cm^2 and distance L = 12 cm between the top of the oven and the gallium-arsenide surface. Calculate the molecular bean epitaxy growth rate (in nm/s) for the effusion oven filled with gallium-arsenide at 1000°C. Given surface density of gallium atom is 6.5×10^{14} per cm^2 and thickness of monolayer = 2.8 $\dot{A}$.

   2+2+6 = 10-marks

2. **Assume 100 keV Tellurium is implanted on a 300 mm Gallium-Arsenide wafer at a dose of 6×10^{14} ions/cm^2. Calculate the peak concentration (in $ions/cm^3$) and the required ion-beam current (in mA) for 1 minute of implantation.**

   Calculate the damage density (per cm^3) caused by 100 keV boron ions if we assume that at 50 keV RP is half of that at 100 keV. Given the spacing between the lattice planes = 0.3 nm and that the energy required to displace a silicon atom = 18 eV. Assume on an average a displaced lattice atom moves 2.5 nm.

   3+3+4 = 10-marks

3. **Electron densities in RIE and HDP are at 10^{10}/cm^3 and 10^{12}/cm^3 respectively. If chamber pressure is 250 mTorr for RIE and 15 mTorr for HDP, estimate he ionization efficiency (in fraction) for both cases.**

   If Do = 24 cm^2/s and E_a = 3 eV, for Arsenic diffusion, calculate the diffusion-length (in cm) after 1 hours of diffusion in Gallium-Arsenide at 1200°C. Repeat the exercise for E_a = 4 eV. Now justify your results with qualitative explanation for the dominant mechanism of diffusion and its dependence on activation energy.

   2+2+2+2+4 = 12-marks

4. **What should be each side (in μm) of a square window lithographically cut to design a 10pF MOS capacitor using silicon dioxide as dielectric of thickness 90$\dot{A}$, assuming completely anisotropic growth of the dielectric.**
   If while fabrication, dielectric-deposition experiences a degree of anisotropy of 0.7, what should be the error (in %) of the capacitor of earlier design.

   For an integrated spiral inductor of 20 nH, what is the radius (in μm) if number of turns = 15? Given permeability of vacuum is: $4\pi\times10^{-7}$ H/m. The inductor is constructed on a silicon dioxide topped p-doped silicon substrate of doping concentration of 10^{15}/ cm^3.

   2+4+2 = 8-marks

TABLE

Impurity	Al	B	O	P	As
k_0	0.002	0.8	0.25	0.35	0.3

Relative Permittivity	Silicon	Silicon Dioxide	Silicon Nitride	Tantalum Pentoxide
	11.7	3.9	7	25

TABLE

(Oxidation in Steam)

Oxidation Temp. (in ^{0}C)	A(μm)	B(μm^2/h)	B/A(μm/h)	τ (h)
1200	0.05	0.72	14.4	0
1100	0.11	0.51	4.64	0
1000	0.226	0.287	1.27	0
920	0.5	0.203	0.40	0

Implant Type	R_p (μm)			σ_P (μm)		
	10 keV	100 keV	1000 keV	10 keV	100 keV	1000 keV
Te (in GaAs)	0.005	0.029	0.3	0.002	0.012	0.09
Zn (in GaAs)	0.009	0.041	0.5	0.005	0.02	0.18
B (in Si)	0.025	0.30	2.0	0.018	0.07	0.15
P (in Si)	0.015	0.12	1.15	0.009	0.05	0.3

Partial Pressure (in Pa) of Gallium and Arsenic over Gallium Arsenide as a Function of Temperature (T)

	800^0C	900^0C	1000^0C
As_2(As-rich)	7×10^3	1.1×10^4	5.0×10^4
Ga (As-rich)	1.0×10^{-5}	7.0×10^{-4}	4.0×10^{-2}
As_2 (Ga-rich)	2×10^{-2}	1.1	6×10^1
Ga (Ga-rich)	6×10^{-3}	5.5×10^{-2}	6×10^{-1}

Some Useful Constants

$E_a(Si)$	k	q (Coul)	μ_n (cm^2/V-s)	μ_p (cm^2/V-s)	Permittivity of Ta_2O_5	R	Avogadro's No.	ξ_o
2.48 *kCal/mol*	1.38×10^{-23} J/K ($=8.617\times10^{-5}$ ev/K)	1.6×10^{-19}	1000	450	25	0.082 lit.-atm/mol-K	6.023×10^{23}	8.85 $\times10^{-14}$ (F/cm)

Molecular Weight

Element	Si	B	P	Ga	As_2	GaAs
Molecular Weight	28.09	10.8	30.97	69.72	149.84	144.63