BITS PILANI DUBAI CAMPUS
EA C415 – INTRODUCTION TO MEMS

SEM I 2012-2013 | **COMPREHENSIVE EXAMINATION** | CLOSED BOOK

Total Marks : 35 | Weightage: 35% | Time Allowed: 3 hours
Date: 8 Jan 2013

INSTRUCTIONS

1. This paper contains **SEVEN (7)** questions and comprises **FOUR (4)** pages. Answer **ALL** questions. Unless specifically stated, all symbols have their usual meanings.

Q1. Why is scaling an important consideration in MEMS structures? Discuss the effect of fluid flow through a channel as the channel dimensions are scaled down. Define Reynold's number. Why is it low for flow of fluids in a microchannel?

(3 marks)

Q2. What are microactuators? Describe how electrostatic forces in a pair of microplates can influence microactuation. Explain the action of a microgripper. Two identical plates of L =800 μm, W = 900 μm are separated by a gap of 2 μm length. One of the plates is fixed. The plates are initially misaligned by 15 % along the length and 20% along the width directions. Calculate the electrostatic forces along the length and width directions for an applied dc voltage of 100 V. The dielectric medium between the two plates is SiO_2.

(6 marks)

Q3. A micro resistor is developed by diffusing phosphorus into intrinsic silicon. The length and width of the opening through which diffusion takes place is 25 μm and 5 μm respectively. The diffusion cycle consists of a 12-minute constant source phosphorus predeposition at 1000 ^oC followed by a 60-minute drive-in at 1100 ^oC. After predeposition, at what depth is the phosphorus concentration reduced to 10% of its value at the surface? Assume that the final diffused layer (after drive-in) is rectangular in cross section with an average phosphorus doping concentration of $0.75C_o$, where C_o represents the final doping concentration at the surface. Determine the value of the micro resistor that is fabricated. If it is required to increase this resistance, what changes in the process are required?

(8 marks)

Q4. When a uniform pressure loading is applied to a rectangular plate with all edges fixed, it can be shown that maximum stress $(\sigma_{yy})_{max}$ occurs at the center of the longer edges and maximum deflection w_{max} of the plate occurs at the centroid.

The terms α and β that refer to the coefficient for maximum deflection and maximum stress respectively, are given in table below for different length-to-width ratios of the plate:

a/b	1	1.2	1.4	1.6	1.8	2.0	∞
α	0.0138	0.0188	0.0226	0.0251	0.0267	0.0277	0.0284
β	0.3078	0.3834	0.4356	0.4660	0.4872	0.4974	0.5

An experiment is performed with a square silicon diaphragm with a 500 μm edge subjected to a pressure loading of 20 MPa. The diaphragm has a thickness 15 μm. Young's modulus for silicon is 190000 MPa. Determine the maximum deflection and the maximum stress produced. Why is a circular diaphragm favoured over rectangular diaphragm?

(4 marks)

Q5. It is desired to fabricate a square silicon diaphragm. The top and side views of the diaphragm are shown in Figure 1:

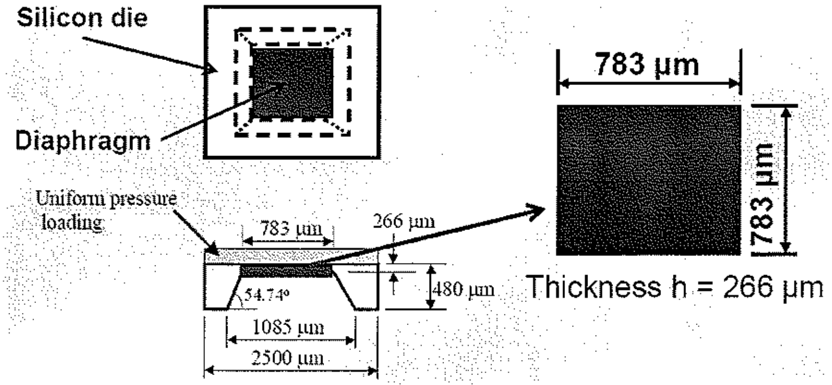


Figure 1

Explain, by clearly mentioning each process step, how the diaphragm can be fabricated.

(5 marks)

Q6. A wet etchant is formed by adding 25 grams of water to a 90 gram mixture of 49.2% HF and 69.51% HNO_3. The mixture has a single-sided etch rate of 5.75 µm/min in silicon. Determine the composition (in wt %) of the etchant used. How much additional HF (in grams) is to be added to the existing mixture so that the etch rate can be increased to 76 µm/min?

(6 marks)

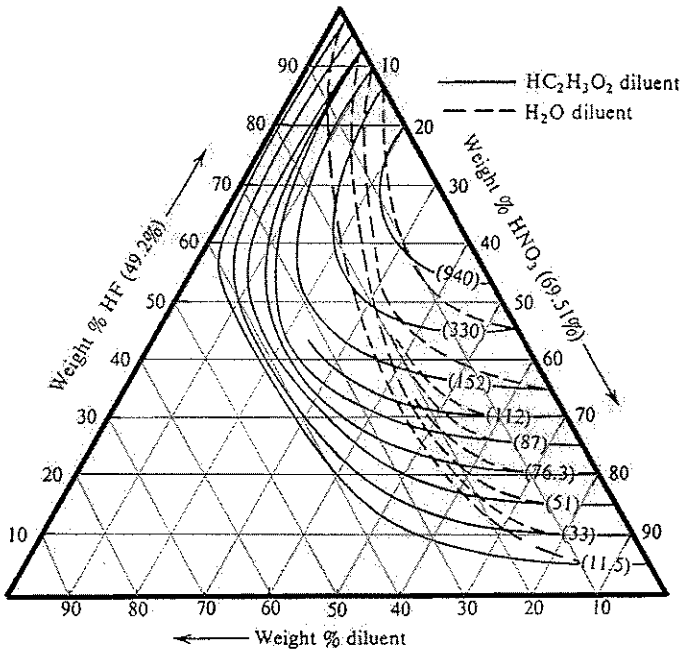


Figure 2

Q7. Explain with a neat sketch, the working principle of a micro-accelerometer. Name one application of the same.

(3 marks)

TABLE OF COMPLEMENTARY EROR FUNCTION

		Complementary Error Function Table											
x	erfc(x)	x	erfc(x)	x	erfc(x)	x	erfc(x)	x	erfc(x)	x	erfc(x)	x	erfc(x)
0	1.000000	0.5	0.479500	1	0.157299	1.5	0.033895	2	0.004678	2.5	0.000407	3	0.00002209
0.01	0.988717	0.51	0.470756	1.01	0.153190	1.51	0.032723	2.01	0.004475	2.51	0.000386	3.01	0.00002074
0.02	0.977435	0.52	0.462101	1.02	0.149162	1.52	0.031587	2.02	0.004281	2.52	0.000365	3.02	0.00001947
0.03	0.966159	0.53	0.453536	1.03	0.145216	1.53	0.030484	2.03	0.004094	2.53	0.000346	3.03	0.00001827
0.04	0.954889	0.54	0.445061	1.04	0.141350	1.54	0.029414	2.04	0.003914	2.54	0.000328	3.04	0.00001714
0.05	0.943628	0.55	0.436677	1.05	0.137564	1.55	0.028377	2.05	0.003742	2.55	0.000311	3.05	0.00001608
0.06	0.932378	0.56	0.428384	1.06	0.133856	1.56	0.027372	2.06	0.003577	2.56	0.000294	3.06	0.00001508
0.07	0.921142	0.57	0.420184	1.07	0.130227	1.57	0.026397	2.07	0.003418	2.57	0.000278	3.07	0.00001414
0.08	0.909922	0.58	0.412077	1.08	0.126674	1.58	0.025453	2.08	0.003266	2.58	0.000264	3.08	0.00001326
0.09	0.898719	0.59	0.404064	1.09	0.123197	1.59	0.024538	2.09	0.003120	2.59	0.000249	3.09	0.00001243
0.1	0.887537	0.6	0.396144	1.1	0.119795	1.6	0.023652	2.1	0.002979	2.6	0.000236	3.1	0.00001165
0.11	0.876377	0.61	0.388319	1.11	0.116467	1.61	0.022793	2.11	0.002845	2.61	0.000223	3.11	0.00001092
0.12	0.865242	0.62	0.380589	1.12	0.113212	1.62	0.021962	2.12	0.002716	2.62	0.000211	3.12	0.00001023
0.13	0.854133	0.63	0.372954	1.13	0.110029	1.63	0.021157	2.13	0.002593	2.63	0.000200	3.13	0.00000958
0.14	0.843053	0.64	0.365414	1.14	0.106918	1.64	0.020378	2.14	0.002475	2.64	0.000189	3.14	0.00000897
0.15	0.832004	0.65	0.357971	1.15	0.103876	1.65	0.019624	2.15	0.002361	2.65	0.000178	3.15	0.00000840
0.16	0.820988	0.66	0.350623	1.16	0.100904	1.66	0.018895	2.16	0.002253	2.66	0.000169	3.16	0.00000786
0.17	0.810008	0.67	0.343372	1.17	0.098000	1.67	0.018190	2.17	0.002149	2.67	0.000159	3.17	0.00000736
0.18	0.799064	0.68	0.336218	1.18	0.095163	1.68	0.017507	2.18	0.002049	2.68	0.000151	3.18	0.00000689
0.19	0.788160	0.69	0.329160	1.19	0.092392	1.69	0.016847	2.19	0.001954	2.69	0.000142	3.19	0.00000644
0.2	0.777297	0.7	0.322199	1.2	0.089686	1.7	0.016210	2.2	0.001863	2.7	0.000134	3.2	0.00000603
0.21	0.766478	0.71	0.315335	1.21	0.087045	1.71	0.015593	2.21	0.001776	2.71	0.000127	3.21	0.00000564
0.22	0.755704	0.72	0.308567	1.22	0.084466	1.72	0.014997	2.22	0.001692	2.72	0.000120	3.22	0.00000527
0.23	0.744977	0.73	0.301896	1.23	0.081950	1.73	0.014422	2.23	0.001612	2.73	0.000113	3.23	0.00000493
0.24	0.734300	0.74	0.295322	1.24	0.079495	1.74	0.013865	2.24	0.001536	2.74	0.000107	3.24	0.00000460
0.25	0.723674	0.75	0.288845	1.25	0.077100	1.75	0.013328	2.25	0.001463	2.75	0.000101	3.25	0.00000430
0.26	0.713100	0.76	0.282463	1.26	0.074764	1.76	0.012810	2.26	0.001393	2.76	0.000095	3.26	0.00000402
0.27	0.702582	0.77	0.276179	1.27	0.072486	1.77	0.012309	2.27	0.001326	2.77	0.000090	3.27	0.00000376
0.28	0.692120	0.78	0.269990	1.28	0.070266	1.78	0.011826	2.28	0.001262	2.78	0.000084	3.28	0.00000351
0.29	0.681717	0.79	0.263897	1.29	0.068101	1.79	0.011359	2.29	0.001201	2.79	0.000080	3.29	0.00000328
0.3	0.671373	0.8	0.257899	1.3	0.065992	1.8	0.010909	2.3	0.001143	2.8	0.000075	3.3	0.00000306
0.31	0.661092	0.81	0.251997	1.31	0.063937	1.81	0.010475	2.31	0.001088	2.81	0.000071	3.31	0.00000285
0.32	0.650874	0.82	0.246189	1.32	0.061935	1.82	0.010057	2.32	0.001034	2.82	0.000067	3.32	0.00000266
0.33	0.640721	0.83	0.240476	1.33	0.059985	1.83	0.009653	2.33	0.000984	2.83	0.000063	3.33	0.00000249
0.34	0.630635	0.84	0.234857	1.34	0.058086	1.84	0.009264	2.34	0.000935	2.84	0.000059	3.34	0.00000232
0.35	0.620618	0.85	0.229332	1.35	0.056238	1.85	0.008889	2.35	0.000889	2.85	0.000056	3.35	0.00000216
0.36	0.610670	0.86	0.223900	1.36	0.054439	1.86	0.008528	2.36	0.000845	2.86	0.000052	3.36	0.00000202
0.37	0.600794	0.87	0.218560	1.37	0.052688	1.87	0.008179	2.37	0.000803	2.87	0.000049	3.37	0.00000188
0.38	0.590991	0.88	0.213313	1.38	0.050984	1.88	0.007844	2.38	0.000763	2.88	0.000046	3.38	0.00000175
0.39	0.581261	0.89	0.208157	1.39	0.049327	1.89	0.007521	2.39	0.000725	2.89	0.000044	3.39	0.00000163
0.4	0.571608	0.9	0.203092	1.4	0.047715	1.9	0.007210	2.4	0.000689	2.9	0.000041	3.4	0.00000152
0.41	0.562031	0.91	0.198117	1.41	0.046148	1.91	0.006910	2.41	0.000654	2.91	0.000039	3.41	0.00000142
0.42	0.552532	0.92	0.193232	1.42	0.044624	1.92	0.006622	2.42	0.000621	2.92	0.000036	3.42	0.00000132
0.43	0.543113	0.93	0.188437	1.43	0.043143	1.93	0.006344	2.43	0.000589	2.93	0.000034	3.43	0.00000123
0.44	0.533775	0.94	0.183729	1.44	0.041703	1.94	0.006077	2.44	0.000559	2.94	0.000032	3.44	0.00000115
0.45	0.524518	0.95	0.179109	1.45	0.040305	1.95	0.005821	2.45	0.000531	2.95	0.000030	3.45	0.00000107
0.46	0.515345	0.96	0.174576	1.46	0.038946	1.96	0.005574	2.46	0.000503	2.96	0.000028	3.46	0.00000099
0.47	0.506255	0.97	0.170130	1.47	0.037627	1.97	0.005336	2.47	0.000477	2.97	0.000027	3.47	0.00000092
0.48	0.497250	0.98	0.165769	1.48	0.036346	1.98	0.005108	2.48	0.000453	2.98	0.000025	3.48	0.00000086
0.49	0.488332	0.99	0.161492	1.49	0.035102	1.99	0.004889	2.49	0.000429	2.99	0.000024	3.49	0.00000080

Appendix

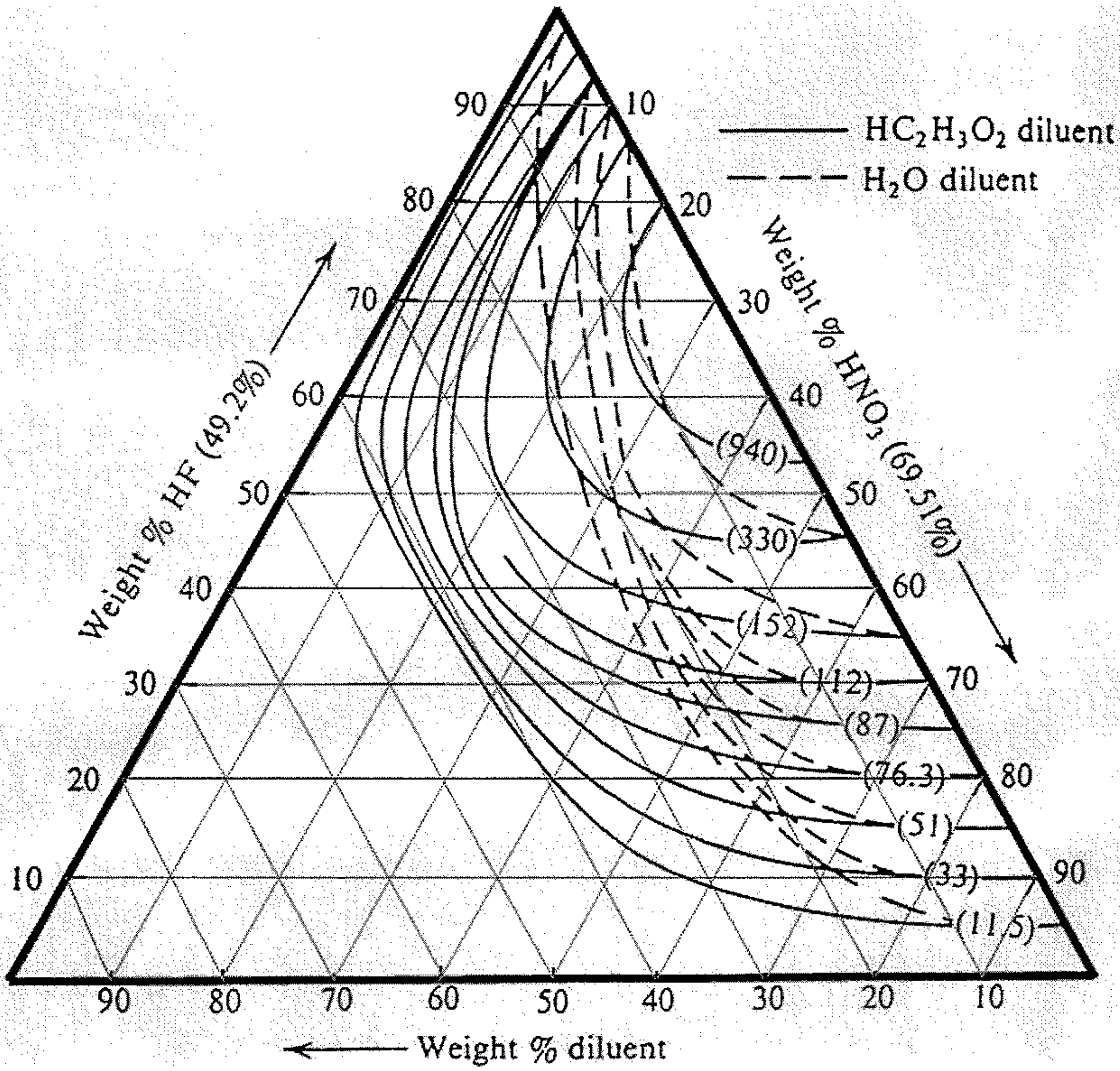
Table of Physical Constants and selected properties of microelectronic materials

	Symbol	Value	*Units*
Boltzmann's constant	k_B (or k)	1.38×10^{-23}	J/K
Electronic charge	q	1.6×10^{-19}	C
Electron-volt	1 eV	1.6×10^{-19}	J
Free electron rest mass	m_0	9.1×10^{-31}	kg
Permittivity of free space	ε_o	8.85×10^{-14}	F/cm
Planck's constant	h	6.626×10^{-34}	J·s
Speed of light	c	3.0×10^{8}	m/s
Thermal voltage (T = 300 K)	kT/q	0.0259	V
Dielectric constant of Si	ε_{Si}	11.8	
Atomic density of Si	C_a	5×10^{22}	cm^{-3}
Dielectric constant of SiO_2	ε_{ox}	3.9	
Dielectric constant of TiO_2	ε_{tox}	80	
Intrinsic carrier concentration in Si at 300 K	n_i	10^{10}	cm^{-3}
Diffusion Coefficient of boron or phosphorus in Si	D_B or D_P	3×10^{-14} at 1000°C 3.1×10^{-13} at 1100°C	cm^2/s
Solid-solubility limit of phosphorus in Si	C_{oP}	1×10^{21} at 1000°C 1.2×10^{21} at 1100°C	cm^{-3}
Solid-solubility limit of boron in Si	C_{oB}	1.7×10^{20} at 1000°C 2.2×10^{20} at 1100°C	cm^{-3}
Mobility of electrons in Si	μ_n	1350	$cm^2V^{-1}s^{-1}$
Mobility of holes in Si	μ_p	450	$cm^2V^{-1}s^{-1}$

End of Paper

Name: ______________________________ ID No.: ____________________

(Attach this sheet with the answer book)



BITS PILANI DUBAI CAMPUS
EA C415 –INTRODUCTION TO MEMS- Test 2

Sem1, 2012-13 | OPEN BOOK | Time Allowed: 50 mins
Total Marks : 20 | Weightage: 20%

INSTRUCTIONS

1. This paper contains **Four (4)** questions and comprises **ONE (1)** page. Answer **ALL** questions. Unless specifically stated, all symbols have their usual meanings.

1. The circular diaphragm of a thin micropressure sensor is made of some material. The thickness of the diaphragm is 13.887 μm and diameter is 600 μm. The diaphragm has its edge rigidly fixed to a silicon die. What is the maximum pressure that can be applied on the diaphragm without exceeding the plastic yielding strength of 7000 MPa for the material. Hence determine the maximum deflection that can be obtained with the diaphragm under the limiting condition. Young's modulus for the material = 0.7×10^{11} Nm^{-2}. Poisson's ratio $\nu = 0.3$

(4 marks)

2 Estimate the equivalent spring constant k and the natural frequency w_n of a cantilever beam element in a microaccelerometer, having a beam length is 1000 micrometer with a mass of 10 mg at the end. The beam is made of silicon whose Young's modulus is 190000 MPa.

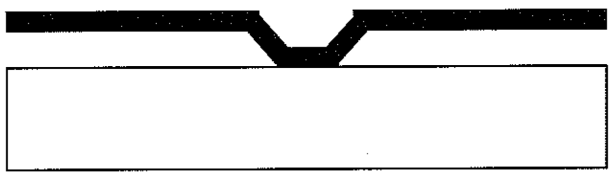
(6 marks)

3 If the cantilever is enclosed in a damping fluid, what effect will it have on the microaccelerometer described in Question 2?

(4 marks)

4 Describe clearly by indicating each process step, the fabrication of a double micro cantilever as shown in figure below, using surface micromachining process. What are the mechanical problems associated with this process?

(6 marks)



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BITS PILANI DUBAI CAMPUS
EA C415 –INTRODUCTION TO MEMS- Test 1

Sem1, 2012-13 CLOSED BOOK Time Allowed: 50 mins
Total Marks : 25 Weightage: 25%

INSTRUCTIONS

1. This paper contains **FIVE (5)** questions and comprises **TWO (2)** pages. Answer **ALL** questions. Unless specifically stated, all symbols have their usual meanings.

1. Four piezo resistors are connected in a Wheatstone Bridge arrangement to form a micro pressure sensor. Draw the typical sensor assembly and the equivalent Wheatstone Bridge circuit. Under what condition does the bridge exhibit highest sensitivity? Explain.

(4 marks)

2. Two plates have identical dimensions of L = W = 200 μm with a gap d = 2 μm. The plates are initially misaligned by 25% in both length and width directions. Pyrex glass is used to fill the gap between the plates. Dielectric constant of pyrex is 4.7. If the voltage across the plates is 50 V DC, how much is the electrostatic force on the electrodes?

(3 marks)

3 A p-type region is diffused in an n-Si wafer. The doping concentration in the p region is 10^{16} cm^{-3}. Assume mobility of holes in Si as 500 $cm^2V^{-1}s^{-1}$. The dimensions of the diffused region are 2μm x 2μm x 1mm.

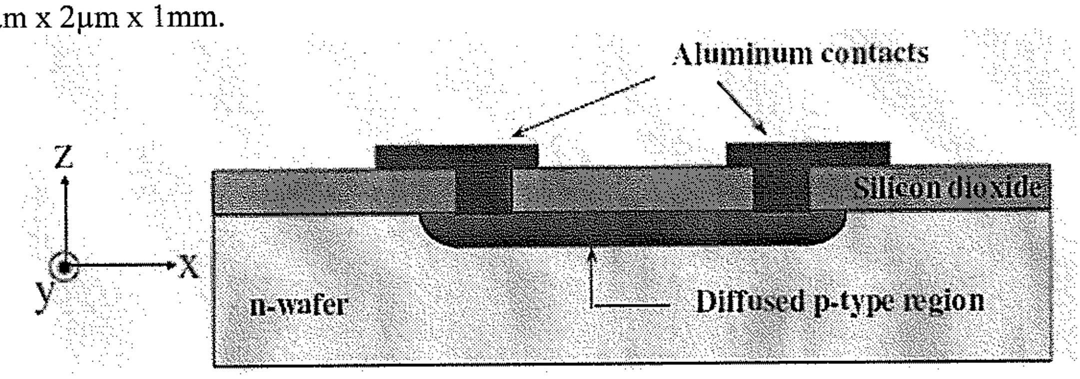


Figure 1

(a) Determine the resistance of the diffused Si layer measured across the length (2 marks)

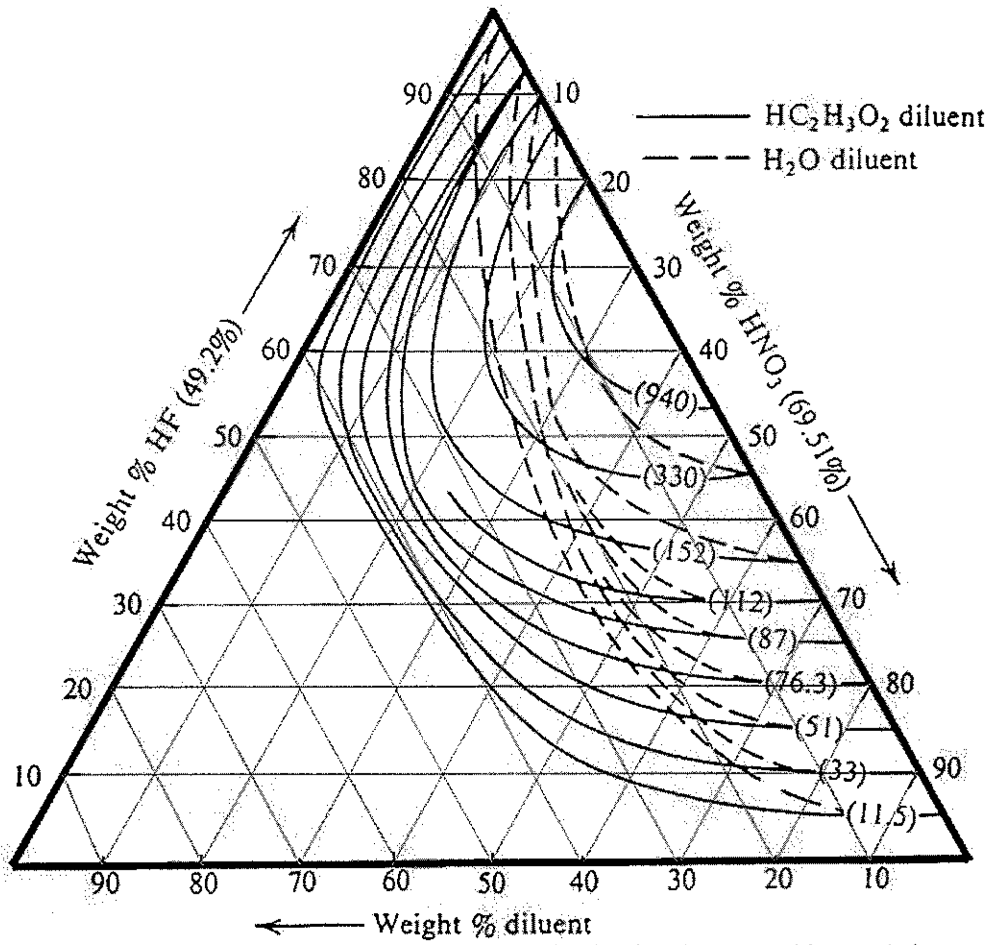
(b) Explain with intermediate steps, how the diffused layer can be realized through microfabrication techniques. Highlight the role of photolithography in the process (6 marks)

(c) Silicon has a peizo resistance $\pi = 10^{-10}$ cm^2/dyne. The fractional change in resistance due to an applied stress σ is given by π.σ. What will be the resistance of the diffused layer due to an stress of $5x10^8$ dynes/cm^2 ? (2 marks)

4. Distinguish between constant source and limited source diffusion. A predeposition cycle with a certain dopant produces a dose of 10^{12} cm^{-2}. A drive-in is done at 1000°C . The dopant concentration at the surface after drive-in is 10^{17} cm^{-3}. For how long is the drive-in performed? Assume that the diffusion coefficient of the dopant in the sample at 1000°C 10^{-14} cm^2/s

(3 marks)

5. Figure 2 shows the isoetch curves for silicon using the HF: HNO_3: diluent system. A wet etchant, formed by adding 4 grams of water to a 16 gram mixture of 49.2% HF and 69.51% HNO_3, is observed to have an etch rate of 76.3 μm/min in silicon. Determine the composition (in wt %) of the etchant used. If more water is added to the mixture, indicate a straight line on the figure along which the composition of the mixture would change. (5 marks)



Etch rates mentioned are for double sided etching in Si and expressed in μm/min

Figure 2

The End

BITS PILANI DUBAI CAMPUS
EA C415 – INTRODUCTION TO MEMS – QUIZ 1

Sem1, 2012 2013 | CLOSED BOOK | Time Allowed: 20 mins
Total Marks : 10 | Weightage: 5%

INSTRUCTIONS

This paper contains **3 (3)** questions. Answer **ALL** questions. Unless specifically stated, all symbols have their usual meanings.

Q1. The Hagen Poiseuille equation describes the rate of volumetric flow of fluid Q as a function of pressure drop ΔP over a length L of a conduit is expressed as $Q = [\pi a^4 \Delta P]/[[8\mu L]$, where a is the radius and μ the viscosity of the fluid. Use scaling laws to estimate the variations of the flow and pressure drop if radius of the tube is reduced by a factor of 10. What will happen to the pressure drop if the tube radius in the order of μm?

(3 marks)

Q2 Describe with a suitable sketch, the working principle of a microgripper where the gripping forces are provided by normal forces or in-plane forces on a pair of parallel plates.

(3 marks)

Q3. Differentiate between constant source and limited source diffusions. On a n-type Si wafer with background concentration $1x10^{15}$ cm^{-3} excess boron is deposited at 975 °C for 60 minutes. The solid solubility of boron in Si at 975°C is $3.5x10^{20}$ cm^{-3}. Diffusion coefficient of boron in Si at 975°C is $1.5x10^{-14}$ cm^2/s. At what depth is the junction formed?

(4 marks)

z	erf(z)	z	erf(z)	z	erf(z)	z	erf(z)	z	erf(z)	z	erf(z)	z	erf(z)	z	erf (z)	z	erf (z)	z	erf (z)
0.00	0.00000	0.40	0.42837	0.80	0.74212	1.20	0.91031	1.60	0.97632	2.00	0.99532	2.40	0.99930	2.80	0.999924	3.20	0.9999938	3.6	0.99999963
0.01	0.01128	0.41	0.43794	0.81	0.74802	1.21	0.91295	1.61	0.97718	2.01	0.99551	2.41	0.99934	2.81	0.999928	3.21	0.9999942	3.61	0.99999966
0.02	0.02257	0.42	0.44744	0.82	0.75383	1.22	0.91553	1.62	0.97801	2.02	0.99570	2.42	0.99937	2.82	0.999932	3.22	0.9999946	3.62	0.99999968
0.03	0.03385	0.43	0.45686	0.83	0.75954	1.23	0.91804	1.63	0.97882	2.03	0.99589	2.43	0.99940	2.83	0.999936	3.23	0.9999950	3.63	0.99999971
0.04	0.04512	0.44	0.46620	0.84	0.76516	1.24	0.92050	1.64	0.97960	2.04	0.99607	2.44	0.99943	2.84	0.999940	3.24	0.9999953	3.64	0.99999973
0.05	0.05639	0.45	0.47546	0.85	0.77068	1.25	0.92289	1.65	0.98035	2.05	0.99624	2.45	0.99946	2.85	0.999943	3.25	0.9999956	3.65	0.99999975
0.06	0.06764	0.46	0.48463	0.86	0.77612	1.26	0.92522	1.66	0.98108	2.06	0.99641	2.46	0.99949	2.86	0.999947	3.26	0.9999959	3.66	0.99999976
0.07	0.07887	0.47	0.49372	0.87	0.78146	1.27	0.92750	1.67	0.98178	2.07	0.99657	2.47	0.99951	2.87	0.999950	3.27	0.9999961	3.67	0.99999978
0.08	0.09009	0.48	0.50273	0.88	0.78670	1.28	0.92972	1.68	0.98247	2.08	0.99672	2.48	0.99954	2.88	0.999953	3.28	0.9999964	3.68	0.99999980
0.09	0.10130	0.49	0.51165	0.89	0.79186	1.29	0.93188	1.69	0.98313	2.09	0.99686	2.49	0.99956	2.89	0.999955	3.29	0.9999966	3.69	0.99999981
0.10	0.11248	0.50	0.52048	0.90	0.79692	1.30	0.93399	1.70	0.98376	2.10	0.99700	2.50	0.99959	2.90	0.999958	3.30	0.9999968	3.70	0.99999982
0.11	0.12364	0.51	0.52923	0.91	0.80190	1.31	0.93605	1.71	0.98438	2.11	0.99714	2.51	0.99961	2.91	0.999960	3.31	0.9999971	3.71	0.99999984
0.12	0.13477	0.52	0.53788	0.92	0.80678	1.32	0.93805	1.72	0.98498	2.12	0.99727	2.52	0.99963	2.92	0.999963	3.32	0.9999972	3.72	0.99999985
0.13	0.14588	0.53	0.54645	0.93	0.81158	1.33	0.94001	1.73	0.98555	2.13	0.99739	2.53	0.99965	2.93	0.999965	3.33	0.9999974	3.73	0.99999986
0.14	0.15696	0.54	0.55493	0.94	0.81629	1.34	0.94190	1.74	0.98611	2.14	0.99751	2.54	0.99966	2.94	0.999967	3.34	0.9999976	3.74	0.99999987
0.15	0.16800	0.55	0.56331	0.95	0.82090	1.35	0.94374	1.75	0.98665	2.15	0.99762	2.55	0.99968	2.95	0.999969	3.35	0.9999978	3.75	0.99999988
0.16	0.17902	0.56	0.57161	0.96	0.82544	1.36	0.94554	1.76	0.98717	2.16	0.99773	2.56	0.99970	2.96	0.999971	3.36	0.9999979	3.76	0.99999989
0.17	0.18999	0.57	0.57981	0.97	0.82988	1.37	0.94729	1.77	0.98767	2.17	0.99784	2.57	0.99971	2.97	0.999973	3.37	0.9999980	3.77	0.99999990
0.18	0.20094	0.58	0.58792	0.98	0.83424	1.38	0.94900	1.78	0.98815	2.18	0.99794	2.58	0.99973	2.98	0.999974	3.38	0.9999982	3.78	0.9999999
0.19	0.21184	0.59	0.59593	0.99	0.83852	1.39	0.95065	1.79	0.98862	2.19	0.99803	2.59	0.99974	2.99	0.999976	3.39	0.9999983	3.79	0.99999991
0.20	0.22270	0.60	0.60385	1.00	0.84271	1.40	0.95226	1.80	0.98907	2.20	0.99812	2.60	0.99976	3.00	0.999977	3.40	0.9999984	3.80	0.99999992
0.21	0.23351	0.61	0.61168	1.01	0.84682	1.41	0.95383	1.81	0.98950	2.21	0.99821	2.61	0.99977	3.01	0.999979	3.41	0.9999985	3.81	0.99999992
0.22	0.24429	0.62	0.61941	1.02	0.85085	1.42	0.95535	1.82	0.98992	2.22	0.99830	2.62	0.99978	3.02	0.999980	3.42	0.9999986	3.82	0.99999993
0.23	0.25501	0.63	0.62705	1.03	0.85479	1.43	0.95683	1.83	0.99032	2.23	0.99838	2.63	0.99979	3.03	0.999981	3.43	0.9999987	3.83	0.99999993
0.24	0.26569	0.64	0.63459	1.04	0.85866	1.44	0.95827	1.84	0.99071	2.24	0.99845	2.64	0.99980	3.04	0.999982	3.44	0.9999988	3.84	0.99999994
0.25	0.27631	0.65	0.64203	1.05	0.86244	1.45	0.95967	1.85	0.99109	2.25	0.99853	2.65	0.99982	3.05	0.999983	3.45	0.9999989	3.85	0.99999994
0.26	0.28688	0.66	0.64937	1.06	0.86615	1.46	0.96103	1.86	0.99145	2.26	0.99860	2.66	0.99983	3.06	0.999984	3.46	0.9999989	3.86	0.99999995
0.27	0.29740	0.67	0.65663	1.07	0.86978	1.47	0.96235	1.87	0.99180	2.27	0.99866	2.67	0.99984	3.07	0.999985	3.47	0.9999990	3.87	0.99999995
0.28	0.30786	0.68	0.66379	1.08	0.87333	1.48	0.96363	1.88	0.99213	2.28	0.99873	2.68	0.99984	3.08	0.999986	3.48	0.9999991	3.88	0.99999995
0.29	0.31826	0.69	0.67085	1.09	0.87681	1.49	0.96487	1.89	0.99246	2.29	0.99879	2.69	0.99985	3.09	0.999987	3.49	0.9999991	3.89	0.99999996
0.30	0.32860	0.70	0.67781	1.10	0.88021	1.50	0.96608	1.90	0.99277	2.30	0.99885	2.70	0.99986	3.10	0.999988	3.50	0.9999992	3.90	0.99999996
0.31	0.33888	0.71	0.68468	1.11	0.88353	1.51	0.96725	1.91	0.99307	2.31	0.99890	2.71	0.99987	3.11	0.999988	3.51	0.9999992	3.91	0.99999996
0.32	0.34910	0.72	0.69144	1.12	0.88679	1.52	0.96839	1.92	0.99336	2.32	0.99896	2.72	0.99987	3.12	0.999989	3.52	0.9999993	3.92	0.99999997
0.33	0.35925	0.73	0.69812	1.13	0.88997	1.53	0.96949	1.93	0.99364	2.33	0.99901	2.73	0.99988	3.13	0.999990	3.53	0.9999993	3.93	0.99999997
0.34	0.36934	0.74	0.70469	1.14	0.89308	1.54	0.97056	1.94	0.99390	2.34	0.99905	2.74	0.99989	3.14	0.999990	3.54	0.9999994	3.94	0.99999997
0.35	0.37936	0.75	0.71117	1.15	0.89612	1.55	0.97160	1.95	0.99416	2.35	0.99910	2.75	0.99989	3.15	0.999991	3.55	0.9999994	3.95	0.99999997
0.36	0.38930	0.76	0.71755	1.16	0.89909	1.56	0.97260	1.96	0.99441	2.36	0.99915	2.76	0.99990	3.16	0.999992	3.56	0.9999995	3.96	0.99999997
0.37	0.39918	0.77	0.72384	1.17	0.90200	1.57	0.97358	1.97	0.99464	2.37	0.99919	2.77	0.99990	3.17	0.999992	3.57	0.9999995	3.97	0.99999998
0.38	0.40898	0.78	0.73003	1.18	0.90483	1.58	0.97452	1.98	0.99487	2.38	0.99923	2.78	0.99991	3.18	0.999993	3.58	0.9999995	3.98	0.99999998
0.39	0.41871	0.79	0.73612	1.19	0.90760	1.59	0.97544	1.99	0.99509	2.39	0.99927	2.79	0.99991	3.19	0.999993	3.59	0.9999996	3.99	0.99999998