SPRING 2024

EE 330 Homework 5 Solutions

1. Length of interconnect = 60um
Width of interconnect = 0.6um No.
of squares = 400/2 = 200

Sheet resistance of interconnect = 23.5 Ω/square

Resistance = 23.5*200 = 4700Ω

Capacitance from interconnect to substrate

Capacitance of Poly 1 substrate from the table given = 84aF/um^2

Interconnect area = 0.6*60 = 36um^2

Capacitance of the substrate= 84 * 10^-18 *36 = 3.024fF

Capacitance between metal and interconnect

Capacitance of Poly and Metal1 from the table given = 56aF/um^2

Area of contact between poly and metal = 36um^2

Capacitance = 56 * 10^-18 *36 = 2.016fF

2. Length of the interconnect = 200um
Width of interconnect = 2um
No of squares = 200/2 = 100.
Resistance = 20 Ω
Sheet resistance = 20/100 = 0.2 Ω/square
Resistivity of copper = 1.72 * 10^-8 Ωm
Thickness = Resistivity/Resistance = 86nm

For Ag =>

Sheet resistance = Resistivity /thickness = 1.59 * 10^-8/ 8.6* 10^-8 = 0.185

Length = W*R/Rs = 216um

3.

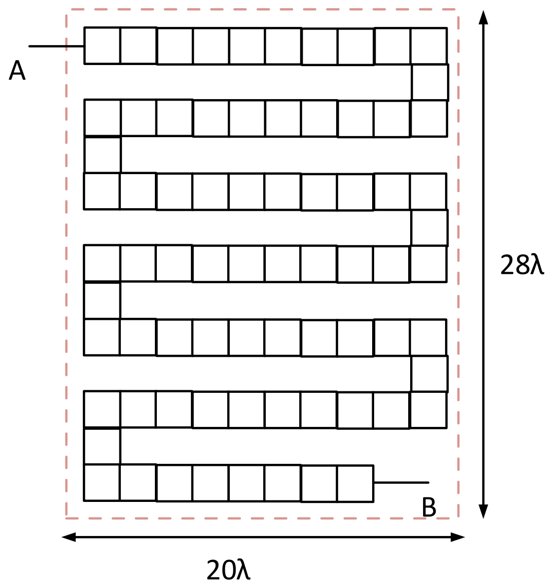
Overlap Cap			
Layers	Overlap Area (µm2)	aF/(µm2)	Cap (af)
Poly-Sub	89.1	84	7484.4
M1- Sub	4.86	27	131.22
M2-sub	15.12	12	181.44
M3-Sub	5.4	3	16.2
M1-Poly	24.3	56	1360.8
M2-Poly	25.92	15	388.8
M3-Poly	12.42	9	111.78
M2-M1	9.72	31	301.32
M3-M1	4.86	13	63.18
M3-M2	6.48	35	226.8
Fringe Cap			
Layers	Length (µm)	aF/(µm)	Cap (af)
Poly-Sub	37.8	0	0
M1- Sub	9	49	441
M2-sub	15.6	33	514.8
M3-Sub	9.6	23	220.8
M1-Poly	5.4	59	318.6
M2-Poly	7.2	38	273.6
M3-Poly	3.6	28	100.8
M2-M1	5.4	51	275.4
M3-M1	3.6	34	122.4
M3-M2	7.2	52	374.4

4. Sheet resistance for high resistance poly = 44Ω\□

Resistance = 3000 Ω

No. of squares = 3000/44 = 68

L = 3W; Let's use a 2λ x 2λ for one square. The following layout is approximately 68 squares and the bounding rectangle meets the aspect ratio requirements.



Problem 5.

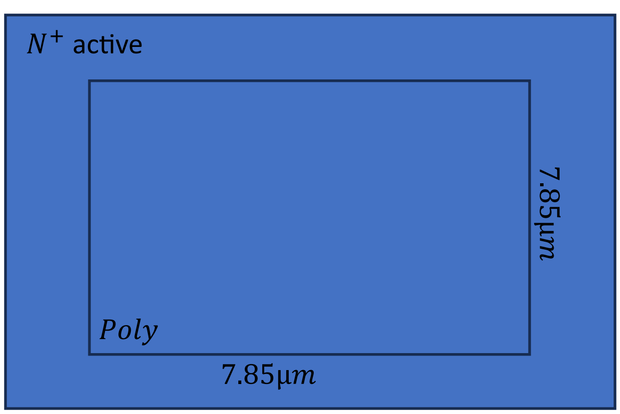
Designing a Capacitor using N^+ active and Poly 1

$$C = C_p \ x \ Area$$

$C_p = 2434 \ x \ 10^{-18}$

$C = 150 \ x \ 10^{-15}$

$$Area = \frac{C}{C_p} = \frac{150 \ x \ 10^{-15}}{2434 \ x \ 10^{-18}} = 61.63\mu m$$



Problem 6

Nominal Value of resistance $= \rho \cdot \frac{\text{Length}}{\text{Area}}$

From table/calculator relating ρ to resistivity

→ $\rho = 22.34\ \Omega \cdot cm = 22.34 \times 10^{-2}\ \Omega m$

→ height (thickness) $= 0.1 \mu m$

→ Area $= 0.4\ \mu m^2$

Length $= 50 \mu m$

⇒ Nominal Value of resistance $= \frac{50}{0.4 \times 10^{-6}} \times 22.34 \times 10^{-2}$

$= 27.925\ M\Omega$

7. Part A:

Begin by calculating the number of squares in each serpentine structure. We can calculate the number of horizontal lines in the serpentine structures as follows:

$$N_{Horizontal} = \frac{Length_{die}}{Width_{Interconnect} + Width_{Spacing}} \quad \frac{1cm}{0.2\mu m} = 50000$$

So we have $50{,}000$ horizontal lines, each $1cm$ long. This amounts to 5×10^9 squares.

To connect these lines, we have $N_{Horizontal} - 1$ vertical segments, each 0.1μ wide. This amounts to $49{,}999$ squares.

In total, we have $5 \times 10^9 + 49999$ squares per resistor. Each metal layer has a resistivity of $0.12\Omega/sq$, so each resistor has a resistance of $600M\Omega$. When combined in parallel, we have a resistance of $200M\Omega$.

Part B:

Each resistor is only $0.1\mu m$ thick, so each can carry a maximum density of $150\mu A$. Placed in parallel, this means the total resistor can carry up to $450\mu A$.

Part C:

$$P = I^2R = [450\mu A]^2[200M\Omega] = 40.5W$$

Problem 8 If the resistance in the interconnect is neglected, it acts as a capacitor in parallel with the input capacitance of the second inverter. $C_I = (C_d)(WL)$

$C_d = 27 af/\mu^2$

a) $R_{pd} = 2K$ $t_{HL} = R_{pd}(C_L)$

$C_I = (.6\mu)^2(27 af/\mu^2)$

$= 9.7Af$

$C_L = 3fF + 9.7aF \simeq 3.01 fF$

$\therefore t_{HL} \simeq 6.02$ psec

b), If $L = 200\mu$

$C_I = (.6)(200)\, 27af/\mu^2 = 3.24 fF$

$\therefore C_L = 3fF + 3.24fF = 6.24fF$

$\therefore t_{HL} = (2K)(6.24fF) = 12.5$ psec

c) The only change with poly (again negleting the interconnect resistance) is Cd=84af/u^2 so

C_I=(0.6)(200)84af/u^2 = 10.1fF so C_L=13.1fF and thus tHL=(2K)(10.1fF)=20.2psec