RFIC Design ELEN 376
Session 3

Instructor: Dr. Allen Sweet
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General Layout Rules

• All Dimensions are in microns.
• Cap is in pF or fF, Ind is in nH, Res is in Ohms.
• Use .5 microns as the finest grid on the CAD Layout Tools.
• ALL metal lines are TRANSMISSION LINES, and must be modeled as such.
• Layout should keep all parasitic elements to a minimum value for best performance.
• Layout should keep chip area to a minimum for lowest cost.
GaAs HBT Virtual Foundry
Design Rules

• Layers and Structures
• Electrical Models
• Current Limits on Metals
• Layout Design Rules
• Design example
Cross Section of Metal and Dielectric Layers
## Layer Definition

<table>
<thead>
<tr>
<th>LAYER NUMBER</th>
<th>NAME</th>
<th>COLOR</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>CM</td>
<td>WHITE</td>
<td>COLLECTOR METAL</td>
</tr>
<tr>
<td>9</td>
<td>TFR</td>
<td>PURPLE</td>
<td>THIN FILM RESISTOR</td>
</tr>
<tr>
<td>10</td>
<td>M1</td>
<td>GREEN</td>
<td>FIRST METAL</td>
</tr>
<tr>
<td>12</td>
<td>NV</td>
<td>BLUE</td>
<td>NITRIDE VIA</td>
</tr>
<tr>
<td>13</td>
<td>M2</td>
<td>RED</td>
<td>SECOND METAL</td>
</tr>
<tr>
<td>14</td>
<td>PV</td>
<td>AQUA</td>
<td>POLYIMIDE VIA</td>
</tr>
<tr>
<td>16</td>
<td>SPV</td>
<td>YELLOW</td>
<td>SCRATCH PROTECT VIA</td>
</tr>
<tr>
<td>18</td>
<td>SV</td>
<td>RED</td>
<td>SUBSTRATE VIA</td>
</tr>
<tr>
<td>63</td>
<td>TXT</td>
<td>WHITE</td>
<td>TEXT</td>
</tr>
</tbody>
</table>
## Layer Thickness

<table>
<thead>
<tr>
<th>LAYER</th>
<th>THICKNESS</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM</td>
<td>1</td>
<td>MICRONS</td>
</tr>
<tr>
<td>TFR</td>
<td>0.3</td>
<td>MICRONS</td>
</tr>
<tr>
<td>M1</td>
<td>2</td>
<td>MICRONS</td>
</tr>
<tr>
<td>NITRIDE</td>
<td>2000</td>
<td>ANGSTR</td>
</tr>
<tr>
<td>POLY</td>
<td>2</td>
<td>MICRONS</td>
</tr>
<tr>
<td>SCRATCH PROTECT</td>
<td>4</td>
<td>MICRONS</td>
</tr>
<tr>
<td>GaAs SUBSTRATE</td>
<td>100</td>
<td>MICRONS</td>
</tr>
</tbody>
</table>
# Layer Resistance

<table>
<thead>
<tr>
<th>LAYER</th>
<th>RESISTANCE IN OHMS PER SQUARE</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM</td>
<td>15</td>
</tr>
<tr>
<td>TFR</td>
<td>50</td>
</tr>
<tr>
<td>M1</td>
<td>0.02</td>
</tr>
<tr>
<td>M2</td>
<td>0.01</td>
</tr>
</tbody>
</table>
## Maximum Current Density

<table>
<thead>
<tr>
<th>LAYER</th>
<th>MAX CURRENT</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM</td>
<td>4</td>
<td>mA per micron</td>
</tr>
<tr>
<td>M1</td>
<td>4</td>
<td>mA per micron</td>
</tr>
<tr>
<td>M2</td>
<td>8</td>
<td>mA per micron</td>
</tr>
<tr>
<td>TFR</td>
<td>1</td>
<td>mA per micron</td>
</tr>
<tr>
<td>HBT Cell</td>
<td>10</td>
<td>mA</td>
</tr>
<tr>
<td>M1 to M2 VIA</td>
<td>3</td>
<td>mA per square micron</td>
</tr>
</tbody>
</table>
Minimum Line Widths

<table>
<thead>
<tr>
<th>LAYER</th>
<th>MINIMUM WIDTH</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM</td>
<td>4</td>
<td>microns</td>
</tr>
<tr>
<td>TFR</td>
<td>4</td>
<td>microns</td>
</tr>
<tr>
<td>M1</td>
<td>4</td>
<td>microns</td>
</tr>
<tr>
<td>NV</td>
<td>2</td>
<td>microns</td>
</tr>
<tr>
<td>M2</td>
<td>5</td>
<td>microns</td>
</tr>
<tr>
<td>PV</td>
<td>2</td>
<td>microns</td>
</tr>
<tr>
<td>SPV</td>
<td>50</td>
<td>microns</td>
</tr>
<tr>
<td>SV</td>
<td>30 in diameter</td>
<td>microns</td>
</tr>
</tbody>
</table>

NOTE: NO DONUTS ARE ALLOWED ON ANY METAL LAYER
## Minimum Same Layer Line Spacing

<table>
<thead>
<tr>
<th>LAYER</th>
<th>MIN SPACING</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM</td>
<td>2</td>
<td>microns</td>
</tr>
<tr>
<td>TFR</td>
<td>3</td>
<td>microns</td>
</tr>
<tr>
<td>M1</td>
<td>4</td>
<td>microns</td>
</tr>
<tr>
<td>NV</td>
<td>4</td>
<td>microns</td>
</tr>
<tr>
<td>M2</td>
<td>4</td>
<td>microns</td>
</tr>
<tr>
<td>PV</td>
<td>4</td>
<td>microns</td>
</tr>
<tr>
<td>SPV</td>
<td>40</td>
<td>microns</td>
</tr>
<tr>
<td>SV</td>
<td>200 edge to edge</td>
<td>microns</td>
</tr>
</tbody>
</table>
Cross Section of a Microstrip Transmission Line

[Diagram of a microstrip transmission line showing the top side metal transmission line, dielectric substrate, and backside metal ground with labels W, H, and information indicating the dimensions and components.]
Transmission Line: M1 or M2

OR

Length=L

W

M1

OR

M2
Transmission Line Cross Section

S.I. SUBSTRATE

POLY AND NITRIDE

M1

M2
ADS Model for a Transmission Line

MLIN
TL7
Subst="MSub1"
W=10.0 um
L=100.0 um
Mod=Kirschning

MSub

MSUB
MSub 1
H=4.0 mil
Er=12.5
Mu=1
Cond=4E+10
Hu=200 mil
T=2 um
TanD=.001
Rough=0 mil
Coupled Transmission Lines

Spacing = S

Width = W
Length = L

M1 or M2

M2 or M1
ADS Model for Coupled Transmission Lines

MCLIN
CLin1
Subst="MSub1"
W=10.0 um
S=5.0 um
L=100.0 um

MSub

MSUB
MSub1
H=4.0 mil
Er=12.5
Mur=1
Cond=4E+10
Hu=200 mil
T=2 um
TanD=.001
Rough=0 mil
Thin Film Resistor: TFR/M1

\[ R = \left( \frac{L}{W} \right) 50 \text{ Ohms} \]
Resistor Cross Section

S.I. SUBSTRATE
ADS Model for Thin Film Resistors

MLIN
TL7
Subst="MSub1"
W=5.0 um
L=150.0 um
Mod=Kirschning

R
R9
R=700 Ohm

MSub

MSUB
MSub1
H=4.0 mil
Er=12.5
Mur=1
Cond=4E+10
Hu=200 mil
T=2 um
TanD=.001
Rough=0 mil
M1 to M2 VIA: M2/M1/PV/NV

Layer enclosure
Is .5 micron
M1 to M2 VIA Cross Section

M2

PV

POLY

M1

NV

NITRIDE

S.I. SUBSTRATE
MIM Capacitor: M1/PV/M2

C = 0.300 fF per Square micron

Layer enclosure is 0.50 micron

Normal Range Is 0.05 pF to 10 pF
Capacitor Cross Section
ADS Model for the MIM Capacitor
Substrate Via:
CM/M1/PV/NV/M2/SV

Layer enclosure
Is .50 micron
Substrate VIA Cross Section

SCRATCH PROTECT

M2

POLY

NITRIDE

PV

NV

S.I. SUBSTRATE

SUBSTRATE VIA

BACKSIDE METAL

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Bond Pad:
CM/M1/PV/NV/M2/SPV

(100 x 100 microns)

Layer enclosure Is .50 micron
Bond Pad Cross Section

S.I. SUBSTRATE

SCRATCH PROTECT

POLY AND NITRIDE
Wafer Probe Pad Pairs

150 microns
M1, M2 Crossover

C = 0.15 fF per Square micron
ADS Model for the M1 to M2 Crossover

![Diagram of ADS Model for the M1 to M2 Crossover]
TFR, M2 Crossover

C = 0.15 fF per Square micron
ADS Model for the TFR to M2 Crossover
Spiral Inductor: M1/M2

Normal Range
Is .1 nH to 5 nH

N=1.25
ADS Spiral Inductor Model

MRIND
L3
Subst="MSub1"
N=1.25
L1=100 um
L2=100 um
W=10 um
S=10 um
Single Finger: HBT Transistor Dummy Cell Layout

Emitter Dimensions:
2 microns X
12 microns

All contacts are M1. No metal may cross over an HBT Cell. Contacts come from the side.
Single Emitter Finger HBT Transistor Gummel Poon Model

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3 Emitter finger (A=3) HBT Transistor: M1/M2/ M1 to M2 VIA
Details of the Three HBT Cell Interconnections

Cell 1  Cell 2  Cell 3

Note: Butt Collectors together
Homework #2: Amplifier Layout
(HBT Transistor is A=3)
Blow up of Amplifier Circuit Elements

- R1
- R2
- HBT
  - A=3
- M1 to M2 VIAs
- Input
- Output
- Ground
Modified Amplifier Schematic
Including All Parasitic Elements
Blow up of Layout Electrical Model
ADS Simulations including Layout Parasitic Elements.