Hand Calculations for RIT’s Advanced CMOS Process

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4-1-2014 HandcalcADV_CMOS.ppt
OUTLINE

Introduction
Calculations
INTRODUCTION

RIT is supporting two different CMOS process technologies. The older p-well CMOS and SMFL-CMOS have been phased out. The SUB-CMOS process is used for standard 3 Volt Digital and Analog integrated circuits. This is the technology of choice for teaching circuit design and fabricating CMOS circuits at RIT. The ADV-CMOS process is intended to introduce our students to process technology that is close to industry state-of-the-art. This process is used to build test structures and develop new technologies at RIT.

RIT p-well CMOS  \( \lambda = 4 \, \mu \text{m} \)  \( \text{Lmin} = 8 \, \mu \text{m} \)
RIT SMFL-CMOS  \( \lambda = 1 \, \mu \text{m} \)  \( \text{Lmin} = 2 \, \mu \text{m} \)
RIT Sub\( \mu \)-CMOS  \( \lambda = 0.5 \, \mu \text{m} \)  \( \text{Lmin} = 1.0 \, \mu \text{m} \)
RIT Advanced-CMOS  \( \lambda = 0.25 \, \mu \text{m} \)  \( \text{Lmin} = 0.5 \, \mu \text{m} \)
RIT Advanced CMOS

- 150 mm Wafers
- \( N_{\text{sub}} = 1 \times 10^{15} \text{ cm}^{-3} \) or 10 ohm-cm, n or p
- \( N_{\text{n-well}} = 1 \times 10^{17} \text{ cm}^{-3} \)
- \( X_j = 2.5 \mu\text{m} \)
- \( N_{\text{p-well}} = 1 \times 10^{17} \text{ cm}^{-3} \)
- \( X_j = 2.5 \mu\text{m} \)
- Shallow Trench Isolation
- \( \text{Field Ox} = 4000 \text{ Å} \)
- Dual Doped Gate n+ and p+
- \( \text{Xox} = 100 \text{ Å} \)
- \( L_{\text{min}} = 0.5 \mu\text{m} \)
- LDD/Nitride Side Wall Spacers
- TiSi2 Silicide
- Tungsten Plugs, CMP, 2 Layers Aluminum

Supply = 3 Volt
\( \text{Vth} = +/- 0.75 \text{ Volts} \)
**RIT ADVANCED CMOS**

**NMOSFET**

- **N**-well
- **P**-well
- **N+ Poly**
- **N+ D/S**
- **P+ well contact**
- **LDD**

**PMOSFET**

- **P**-well
- **N**-well
- **P+ Poly**
- **P+ D/S**
- **n+ well contact**
- **LDD**

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Hand Calculations for Advanced CMOS Process

**LAMBDA, Lmin, Ldrawn, Lmask, Lpoly, Lint, Leff, L**

- **Lambda** = design rule parameter, \( \lambda \), ie 0.25\( \mu \)m
- **Lmin** = min drawn poly length, \( 2\lambda \) 0.50\( \mu \)m
- **Ldrawn** = what was drawn
- **Lmask** = ? Depends on +/-bias 1.00\( \mu \)m x 5
- **Lpoly** = after poly etch
- **Lpoly after poly etch** 0.40\( \mu \)m
- **Lpoly after poly reoxidation** 0.35\( \mu \)m
- **Lresist after photo** (resist trimming??) 0.50\( \mu \)m

Source at 0 V

Drain at 3.3V

- **Lint** = distance between junctions, including under diffusion 0.30\( \mu \)m
- **Leff** = distance between space charge layers 0.20\( \mu \)m
- **L** = distance between space charge layers, when Vd= what it is 0.11\( \mu \)m

Ldrawn = what was drawn

Internal Channel Length, \( L_{\text{int}} \) = distance between junctions, including under diffusion
Effective Channel Length, \( L_{\text{eff}} \) = distance between space charge layers, \( V_d = V_s = 0 \)
Channel Length, \( L \), = distance between space charge layers, when \( V_d = \text{what it is} \)
Extracted Channel Length Parameters = anything that makes the fit good (not real)
Width of Space Charge Layer:

\[ W = (W_1 + W_2) = [ (2\varepsilon/\theta) (\Psi_o + V_R) (1/N_A + 1/N_D)]^{1/2} \]

Maximum Electric Field:

\[ E_o = - \left[ (2q/\varepsilon) (\Psi_o + V_R) (N_A N_D/(N_A + N_D)) \right]^{1/2} \]

Let \( N_A = N_D = 1E17 \)

<table>
<thead>
<tr>
<th>Well Doping</th>
<th>Bias (volts)</th>
<th>SC Layer (µm)</th>
<th>Efield (V/cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1E17</td>
<td>0</td>
<td>0.07</td>
<td>-1.09E5</td>
</tr>
<tr>
<td>1E17</td>
<td>3</td>
<td>0.14</td>
<td>-2.42E5</td>
</tr>
</tbody>
</table>

Breakdown Electric Field = 3E5 V/cm

\[ \varepsilon = \varepsilon_o \varepsilon_r = 8.85E-12 \ (11.7) \ F/m \]

\[ 8.85E-14 \ (11.7) \ F/cm \]
USING EXCEL SPREADSHEET FOR CALCULATIONS

pn_electrostatics_current_temp.xls

| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S |
| **CONSTANTS** | **VARIABLES** | | | | | | | | | | | | | | | | | |
| 11 | K | 1.38E-23 JK | | | | | | | | | | | | | | | | |
| 12 | q | 1.60E-19 Coul | Temp= 300°K | | | | | | | | | | | | | | | |
| 13 | Ego | 1.12 eV | | | | | | | | | | | | | | | |
| 14 | eo | 8.85E-14 F/cm | Nd = 1.00E+17 cm^-3 | | | | | | | | | | | | | | |
| 15 | w | 11.7 | Na = 1.00E+17 cm^-3 | | | | | | | | | | | | | | |
| 16 | nd | 1.45E+10 cm^-3 | | | | | | | | | | | | | | |
| 17 | Breakdown E= | 2.00E+05 V/cm | Vr= 0 Volts | Reverse Bias Voltage | | | | | | | | | | | | | |

C A L C U L A T I O N S:

\[
E_g = E_{go} - \left( \alpha T^2 + (T+8) \right)
\]

\[
\nu_s^2 = A \cdot T^3 \cdot s / \sqrt{E_g / \sqrt{K\theta}}
\]

\[
K_{\theta} = \frac{W_1}{N_0 \cdot W_1 (N+H_d)}
\]

\[
V_{hi} = (K\theta / q) \cdot \ln(NaNd/hW1)
\]

\[
W = \left( \frac{x}{2} + W_1 \right) H / V_{hi} + W_1 (1 + N_a + N_d) / 0.5
\]

\[
W_1 = W / N_0 (N+H_d)
\]

\[
W_2 = W / N_0 (N+H_d)
\]

\[
E_o = \left[ \left( \frac{q \cdot c / \sqrt{K\theta}}{W_0 + V_{hi} (N_a + H_d)} \right) \cdot 0.5 \right]
\]

\[
C_f = \frac{q \cdot c / \sqrt{K\theta}}{W_0 + V_{hi} (N_a + H_d)} \cdot 0.5
\]

\[
\frac{dI = I_s}{C_f} = \frac{V}{K\theta / (V_{hi} / N_0)} - 1
\]

\[
I_s = CT^2 \exp \left( \frac{qE_o}{K\theta} \right)
\]

\[
I_s = 9.73E-13
\]

\[
V = -9.72785E-13
\]

\[
I_d = -9.72785E-13
\]

\[
I_s = 9.72785E-13
\]

\[
I_s = 9.72785E-13
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I_s = 9.72785E-13
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I_s = 9.72785E-13
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\]

\[
I_s = 9.72785E-13
\]
The well implant dose is estimated from the selected values of well doping and junction depth of 2.5µm. The dose is the total number of impurity atoms per cm$^2$ in the well.

\[
\text{Dose} = \int \text{Nwell} \, dx = \text{Nwell} \times X_j \quad \text{if we assume the well is uniformly doped as N}_s \text{ from the surface } x=0 \text{ to the junction } x=X_j
\]

\[
= N_s \times X_j
\]

\[
= (1E17 \text{ cm}^{-3}) \times (2.5E^{-4} \text{ cm})
\]

\[
\text{Dose} = 2.5 \times 10^{13} \text{ cm}^{-2}
\]
HAND CALCULATIONS FOR ADV-CMOS WELL

Well calculations for junction depth, well sheet resistance, well surface concentration and average well doping

Given: Dose=2.5E13, Drive-in Time=6 Hrs Drive in Temp = 1100 C
Starting wafer 1E15 cm^-3 from 10 ohm-cm

\[ N(x,t) = \frac{Q'(tp)}{\sqrt{\pi Dt}} \exp\left(-\frac{x^2}{4Dt}\right) \]

Surface concentration

\[ N_{ave} = \frac{\text{Dose}}{x_j} \]
**WELL DRIVE CALCULATIONS**

**GIVEN**
- Starting Wafer Resistivity: \( \rho = 10 \ \text{ohm-cm} \)
- Starting Wafer Type:
  - n-type = 1
  - p-type = 1

**Pre Deposition Ion Implant Dose**
- \( 2.50 \times 10^{13} \ \text{ions/cm}^2 \)

**Drive-in Temperature**
- 1100 \(^\circ\text{C}\)

**Drive-in Time**
- 360 minutes

**CALCULATE**

**Calculation of Diffusion Constants**

<table>
<thead>
<tr>
<th>Material</th>
<th>( D_0 ) (cm(^2)/s)</th>
<th>( E_A ) (eV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boron</td>
<td>0.76</td>
<td>3.46</td>
</tr>
<tr>
<td>Phosphorous</td>
<td>3.85</td>
<td>3.66</td>
</tr>
</tbody>
</table>

**Calculations**
- Substrate Doping = \( \frac{1}{(q \ \mu_{\text{max}} \ \rho)} \)
- \( x_j \) after drive-in = \( (4 \ \mathcal{D} \ \mathcal{d} / \mathcal{Q} \ \mathcal{A}) \ln (N_{\text{sub}} / (\pi \ \mathcal{D} \ \mathcal{d} \ \mathcal{t} \ \mathcal{d})^{0.5})^{0.5} \)
- Average doping \( \mathcal{N}_{\text{ave}} = \mathcal{D} \ / \ x_j \)
- Mobility \( (\mu) \) at Doping equal to \( \mathcal{N}_{\text{ave}} \)
- Sheet Resistance = \( \frac{1}{(q \ (\mu(N_{\text{ave}}) \ Dose)} \)
- Surface Concentration = \( \frac{\text{Dose}}{(pDt)^{0.5}} \)

**Results**
- Pre Deposition Dose: \( 2.50 \times 10^{13} \ \text{atoms/cm}^2 \)
- \( x_j \) after drive-in = 2.47 \( \mu \text{m} \)
- Average doping \( \mathcal{N}_{\text{ave}} = 1.01 \times 10^{17} \ \text{atoms/cm}^3 \)
- Mobility \( (\mu) \) at Doping equal to \( \mathcal{N}_{\text{ave}} \) = 718 \( \text{cm}^2/\text{V-s} \)
- Sheet Resistance = 348.2 ohms
- Surface Concentration = \( 2.63 \times 10^{17} \ \text{cm}^{-3} \)
## WELL CALCULATIONS

### Given
- \( N_s = 1 \times 10^{17} \text{cm}^{-3} \)
- \( X_j = 2.5 \mu \text{m} \)
- Dose = \( 2.5 \times 10^{13} \text{ cm}^{-2} \)
- Well Drive = 6hr, 1100°C

### Calculated
- \( N_s X_j \) (Nave cm\(^{-3}\))
- \( \rho_s \mu \text{ } \Omega \)

<table>
<thead>
<tr>
<th></th>
<th>( N_s )</th>
<th>( X_j )</th>
<th>Nave cm(^{-3})</th>
<th>( \rho_s ) µΩ</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-well</td>
<td>2.63E17</td>
<td>2.47</td>
<td>1.01E17</td>
<td>348</td>
</tr>
<tr>
<td>P-well</td>
<td>2.54E17</td>
<td>2.80</td>
<td>8.93E16</td>
<td>768</td>
</tr>
<tr>
<td>Photoresist</td>
<td>13000Å</td>
<td>Boron Exmax</td>
<td>105KeV</td>
<td>Phos Emax</td>
</tr>
<tr>
<td>Oxide</td>
<td>4000Å</td>
<td>Boron Emin</td>
<td>80KeV</td>
<td>Phos Emin</td>
</tr>
</tbody>
</table>

### IMPLANT MASK CALCULATOR

Enter 1 - Yes  0 - No in white boxes

<table>
<thead>
<tr>
<th>DOPANT SPECIES</th>
<th>MASK TYPE</th>
<th>ENERGY</th>
</tr>
</thead>
<tbody>
<tr>
<td>B11</td>
<td>Resist</td>
<td>1</td>
</tr>
<tr>
<td>BF2</td>
<td>Poly</td>
<td>0</td>
</tr>
<tr>
<td>P31</td>
<td>Oxide</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Nitride</td>
<td>0</td>
</tr>
</tbody>
</table>

Thickness to Mask >1E15/cm\(^3\) Surface Concentration = 12753.72 Å
**SILVACO ATHENA WELL SIMULATION**

**P-well**
- Dose=7.0E13
- Energy=120KeV
- Drive 6 hr, 1100 C
- Find:
  - $N_{surface}=1E17$
  - $N_{sti}=1E17$
  - $X_j=3.0 \text{um}$

**N-well**
- Dose=3E13
- Energy=170KeV
- Drive 6 hr, 1100 C
- Find
  - $N_{surface}=1E17$
  - $N_{sti}=2E16$
  - $X_j=3.0 \text{um}$
Oxide Growth Calculations

Step 4 - Pad oxide 1/3 nitride thickness so oxide target is 500 Å
55 min at 1000 C dry O2 gives 500 Å, Recipe 250

Step 10 – Pad Oxide Trench Liner, 500Å, Recipe 250

Step 23 - Well Drive is in Nitrogen: no oxide growth, Recipe 11

Step 30 - Gate Oxide 100Å, 40 min at 900 C dry O2, Recipe 213

Fowler/Nordheim Tunneling Consideration: 3 volt power supply and max field of 4E6 V/cm gives Xox min of 75 A,

pick 100 A for gate oxide target thickness

Step 36 - Poly Reox, 500 Å, Recipe 250

Step 52 - DS Anneal will be in N2: no oxide growth, 900C for 30 min., Recipe ???

Step 67 – Sinter, Recipe 101 no oxide growth
Poly Thickness and Sheet Resistance Calculations

Poly thickness needs to mask D/S implants (see next page)
Target should be 4000 Å, USL 4500 Å, LSL 3500 Å

\[ \text{Rhos} = \frac{1}{(q \mu \text{Dose})} \] and Dose is 4E15 for both, \( \mu = 20 \) and 10

Poly Doping by Ion Implant, N+, Rhos=78 ohms
Poly Doping by Ion Implant, P+, Rhos=156 ohms
**DRAIN/SOURCE IMPLANT ENERGY CALCULATIONS**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Min Thickness</th>
<th>E max (B11)</th>
<th>E max (P31)</th>
<th>E used (B11)</th>
<th>E used (P31)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resist</td>
<td>13,000 Å</td>
<td>105</td>
<td>210</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Poly</td>
<td>3,500 Å</td>
<td>50</td>
<td>80</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Oxide</td>
<td>4,000 Å</td>
<td>75</td>
<td>115</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitride</td>
<td>3,000 Å</td>
<td>95</td>
<td>145</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Implant Mask Calculator**

Enter 1 - Yes 0 - No in white boxes

<table>
<thead>
<tr>
<th>DOPANT SPECIES</th>
<th>MASK TYPE</th>
<th>ENERGY</th>
</tr>
</thead>
<tbody>
<tr>
<td>B11</td>
<td>Resist</td>
<td>0</td>
</tr>
<tr>
<td>BF2</td>
<td>Poly</td>
<td>1</td>
</tr>
<tr>
<td>P31</td>
<td>Oxide</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Nitride</td>
<td>0</td>
</tr>
</tbody>
</table>

Total thickness to mask >1E15/cm³ Surface Concentration: 3,417.1483 Å

**Surface Concentration in Angstroms:** 3,417,148.3
These simulations show that 3000 A of poly and nitride spacer is enough to block P31 implants from reaching the channel (region 1), the n+ D/S implant profile is shown in region 2, the LDD n-D/S implant profile is shown in region 3, both after 900 C, 30 min anneal. Note doping ~1E20 in D/S and ~1E18 in LDD/LDS and xj ~ 0.6 μm
D/S Sheet Resistance and Junction Depth Calculations
(Rhos=1/(quDose)), Xj depends on implant energy so Xj~0.2
N-LDD implant dose 4E13 and 50KeV, μ=100, Rhos=1250 ohms
N+ D/S implant dose 4E15 and 50 KeV, μ=100, Rhos=12.5 ohms
P-LDD implant dose 4E13 and 50 KeV, μ=75, Rhos=1667 ohms
P+ D/S implant dose 4E15 and 50 KeV, μ=75, Rhos=16.7 ohms
Silicide Consideration: will reduce sheet resistance to as low as 5 ohms

Drain Source Space Charge Layer Calculations
N-D/S using Nd=1E18, Na=1E17 gives W=0.10um at 0V and W=0.21um at 3V
N+D/S using Nd=1E20, Na=1E17 gives W=0.11um at 0V and W=0.23um at 3V
P-D/S using Na=1E18, Nd=1E17 gives W=0.10um at 0V and W=0.21um at 3V
P+D/s using Na=1E20, Nd=1E17 gives W=0.11um at 0V and W=0.23um at 3V
HAND CALCULATIONS FOR ADV-CMOS VT

Threshold Voltage Calculations, target +0.75 and –0.75 volts

N-MOSFET VT, Nss=1E11, Xox=100 A, Na=1E17, VT=0.25, Wdmax=.103um
Dose=1.07E12 x 2 = 2.15E12 Boron

P-MOSFET VT, Nss=1E11, Xox=100 A, Nd=1E17, VT=-0.34, Wdmax=.103um
Dose=8.76E11 x 2 = 1.75E12 Phosphorous

N-Field VT, Nss=1E11, Xox=4000 A, Na=1E17, VT=17 volts
P-Field VT, Nss=1E11, Xox=4000 A, Nd=1E17, VT=-20 volts
No channel stop needed
## VT CALCULATIONS

<table>
<thead>
<tr>
<th>CONSTANTS</th>
<th>VARIABLES</th>
<th>CHOICES</th>
</tr>
</thead>
<tbody>
<tr>
<td>T = 300 K</td>
<td>Na = 1.00E+17 cm^{-3}</td>
<td>Aluminum gate 0</td>
</tr>
<tr>
<td>KT/q = 0.026 volts</td>
<td>Nd = 1.00E+17 cm^{-3}</td>
<td>n+ Poly gate 1</td>
</tr>
<tr>
<td>ni = 1.45E+10 cm^{-3}</td>
<td>Nss = 1.00E+11 cm^{-2}</td>
<td>p+ Poly gate 0</td>
</tr>
<tr>
<td>Eo = 8.85E-14 F/cm</td>
<td>Xox = 100 Ang</td>
<td>N substrate 0</td>
</tr>
<tr>
<td>Er si = 11.7</td>
<td>Er SiO2 = 3.9</td>
<td>P substrate 1</td>
</tr>
<tr>
<td>Eaffinity = 4.15 volts</td>
<td>q = 1.60E-19 coul</td>
<td>Desired VT 0.75</td>
</tr>
<tr>
<td>Eg = 1.124 volts</td>
<td></td>
<td>or Delta VT 20</td>
</tr>
</tbody>
</table>

### CALCULATIONS:

- **METAL WORK FUNCTION**
  \[ = 4.12988528 \text{ volts} \]
- **SEMICONDUCTOR POTENTIAL**
  \[ = \pm 0.409409834 \text{ volts} \]
- **OXIDE CAPACITANCE / CM2**
  \[ = 3.4515E-07 \text{ F/cm2} \]
- **METAL SEMI WORK FUNCTION DIFF**
  \[ = -0.998421306 \text{ volts} \]
- **FLAT BAND VOLTAGE**
  \[ = -1.044777963 \text{ volts} \]
- **THRESHOLD VOLTAGE**
  \[ = 0.25126959 \text{ volts} \]
- **DELTA VT = VT_{desired} - VT**
  \[ = 0.49873041 \text{ volts} \]
- **IMPLANT DOSE**
  \[ = 1.07586E+12 \text{ ions/cm}^2 \times 2 = 2.15171E+12 \text{ ions/cm}^2 \]
  where + is Boron, - is Phosphorous
- **IMPLANT DOSE FOR GIVEN Delta VT**
  \[ = 4.31438E+13 \text{ ions/cm}^2 \times 2 = 8.62875E+13 \text{ ions/cm}^2 \]
- **Vt WITH GIVEN DOSE**
  \[ = 0.552587857 \text{ volts} \] assume 1/2 dose in Si

### RESULTS:

- **Wdmax** = 0.103 \mu m
- **2.15171E+12** ions/cm²
- **8.62875E+13** ions/cm²

Select one type of gate

Select one type of substrate

Choose 1=yes, 0=No
**ION IMPLANT RANGE**

- **Projected Range, $R_P$ (um)**
- **Implantation Energy (KeV)**

- **B**
  - B11~30KeV
- **P**
  - P31~50KeV
- **Sb**

Select

- **As**

- **$10^{-2}$**
- **$10^{-1}$**
- **1**
- **100**
- **1,000**
BLANKET PMOS & NMOS VT ADJUST IMPLANT

2.15E12, 30keV, B_{11}

P-well

N-well

Substrate 10 ohm-cm
PMOS VT IMPLANT

3.90E12, 50keV, P_{31}

P-well

N-well

Substrate 10 ohm-cm
## ADV-CMOS 150 PROCESS

**CMOS Versions 150, one level Metal**

1. ID01  
2. DE01  
3. CL01  
4. OX05--- pad Ox 500A, 1000C, 45min  
5. CV02- 1500 Å, ~30min  
6. PH03 –1- STI  
7. ET29 etch shallow trench, 4000A  
8. ET07-ash  
9. CL01  
10. OX05 – pad oxide, 500 A  
11. CV03 – CVD oxide trench fill  
11.1 OX07 - Anneal  
12. CM01 – Trench CMP  
13. CL02 - CMP_Clean  
14. CL01-rca clean  
15. ET19 hot phos  
16. PH03-2-n-well, 1.3um thick resist  
17. IM01 3E13, P31, 180 KeV  
18. ET07-ash  
19. PH03 – 3 – p-well  
20. IM01 – 3E13, B11, 150KeV  
21. ET07 -ash  
22. CL01  
23. OX06 well drive, 6hr 1100C  
24. IM01 blanket implant  
25. PH03 – 4 - VT adjust  
26. IM01 adjust  
27. ET07  
28. CL01  
29. ET06 oxide etch  
30. OX06 gate oxide  
31. CV01 poly dep  
32. PH03 - 5 - poly  
33. ET08 poly etch  
34. ET07  
35 CL01  
36 OX05 pad oxide  
37. PH03 –6- p LDD  
38. IM01 p LDD  
39. ET07  
40. PH03 –7- n LDD  
41. IM01 n LDD  
42. ET07  
43. CL01  
44. CV02 nitride spacer dep  
45. ET39 spacer etch  
46. PH03 – 8 - N+D/S  
47. IM01 – N+D/S  
48. ET07  
49. PH03 – 9- P+ D/S  
50. IM01 – P+ D/S  
51. ET07  
52. CL01  
53. OX08 – DS Anneal  
54. ME03 HF dip & Co/Ti  
55. RT01  
56. ET11 Ti Etch  
57. RT02  
58. CV03 – LTO  
59. PH03 – 10 CC  
60. ET10  
61. ET07  
62. CL01  
63 ME01 Aluminum  
64. PH03 -11- metal  
65. ET15 plasma Al Etch  
66. ET07  
67. SI01  
68. SEM1  
69. TE01  
70. TE02  
71. TE03  
72. TE04

(Revision 9-20-04)
ETCH RATES

STI etch rates 1000A/min Nitride, 500A/min Oxide, 5000A/min Si, 1000A/min PR

Hot Phos Nitride Etch Rate 80A/min, 45 min to etch 1500A nitride

Poly Etch Lam 490, Gap 1.5, 325 mTorr, 140 w, 150 sccm SF6, 15sccm O2, rate=6000Å/min

Sidewall spacer etch, Power=250 Watts, Pressure=40 mTorr, SF6=30 sccm, CHF3=30 sccm, Nitride Etch Rate=1250 A/min, Nitride Etch %NU ~ 4%, Oxide Etch Rate~ 950 A/min Oxide Etch %NU~ 10% , Selectivity Nitride:Oxide 1.3:1

H2SO4/H2O2 (1:2) Ti etch for silicide, at 100°C (set plate temperature to 150°C), Rate ~500Å/min

Aluminum Etch Rate LAM4600 ~10,000Å/min.
DEPOSITION RATES

LPCVD Nitride dep rate at 810°C = 50 Å/min.
1500 Å for STI Stop, time = 30 min
4000 Å for Side Wall Spacer = 80 min

PECVD TEOS Oxide dep rate 91Å/sec
10,000 Å trench fill
4000 Å for contact cuts

LPCVD Poly dep rate at 610°C = 75 Å/min
4000 Å gate deposition time = 53 min.

Aluminum Sputter dep rate at 2000 w = 300Å/min.
7500 Å metal one dep time = 25 min

Ti Sputter dep rate, 4” target, 350w, 5mTorr = 100Å/min
700 Å Ti dep time = 7 min

Ti Sputter dep rate, 8” target, 750w, 5mTorr=176Å/min.
700 Å Ti dep time = 4 min
## ADV-CMOS PHOTO

<table>
<thead>
<tr>
<th>Level Name</th>
<th>Coat Recipe</th>
<th>Coat Xpr µm</th>
<th>Dose mj/cm²</th>
<th>Develop Recipe</th>
<th>Dev Time</th>
<th>Post Bake Time at 140°C</th>
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</thead>
<tbody>
<tr>
<td>STI</td>
<td>Coat.rcp</td>
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<td>develop.rcp</td>
<td>50s</td>
<td>1 min.</td>
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<td>Coatmtl.rcp</td>
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<td>185</td>
<td>Devmtl.rcp</td>
<td>75s</td>
<td>2 min.</td>
</tr>
<tr>
<td>P-well</td>
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<td>Devmtl.rcp</td>
<td>75s</td>
<td>2 min.</td>
</tr>
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<td>Vtn</td>
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<tr>
<td>Vtp</td>
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<td>DevFac.rcp</td>
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<td>1 min.</td>
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<tr>
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<tr>
<td>Ldd N</td>
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<td>N+ D/S</td>
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<td>160</td>
<td>develop.rcp</td>
<td>50s</td>
<td>1 min.</td>
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<tr>
<td>P+ D/S</td>
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<td>1.0</td>
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<td>develop.rcp</td>
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<tr>
<td>CC</td>
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<tr>
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<td>160</td>
<td>Devmtl.rcp</td>
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<td>2 min.</td>
</tr>
</tbody>
</table>
ORIGINAL ADV-CMOS PROCESS FLOW

500Å Pad Ox.
- Bruce Tube 4

1500Å CVD Nitride
- LPCVD

STI Litho- level 1

4000Å Plasma etch
- Lam 490

PR Ash
RCA Clean

500Å Pad Oxide
- Bruce Tube 1

CVD Trench fill- P-5000
Anneal – Bruce Tube 1

Trench CMP
CMP Clean

RCA Clean
Hot Phos. Nitride strip

N-well Litho
- Level 2

N-well implant
- P31, 3E13 cm⁻² E=180KeV

Ash
P-well Litho - level 3

P-well implant
- B11, 3E13 cm⁻² E=150KeV

Ash, RCA clean
Drive in- 6hr 1100C-Tube 1

Xj approx. 3 μm
**PROPOSED ADV-CMOS PROCESS FLOW**

- **500Å Pad Ox.**
  - Bruce Tube 4

- **1500Å CVD Nitride**
  - LPCVD

- **STI Litho- level 1**

- **4000Å Plasma etch**
  - Lam 490

- **PR Ash**
  - RCA Clean

- **500Å Pad Oxide**
  - Bruce Tube 1

- **N-well Litho**
  - Level 2

- **N-well implant**
  - P31, 8e13 cm⁻² E=80 KeV

- **P-well Litho**
  - Level 3

- **P-well implant**
  - B11, 3e13 cm⁻² E=170 KeV

- **PR Ash**
  - RCA Clean

- **Drive in- 6hr 1100°C-Tube 1**

- **X_j approx. 3 μm**

- **CVD Trench fill- P-5000 Anneal –Bruce Tube 1**

- **Trench CMP**
  - CMP Clean

- **RCA Clean**
  - Hot Phos. Nitride strip
SIMULATION: ORIGINAL PROCESS WELL PROFILES

Problems with Boron Penetration of Masking Resist
### WELL PARAMETERS

<table>
<thead>
<tr>
<th></th>
<th>Design Parameters</th>
<th>Old Process Simulation</th>
<th>New Process Simulation</th>
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<tr>
<td><strong>N well</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Dose</td>
<td>3E13</td>
<td>3E13</td>
<td>3E13</td>
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<tr>
<td>Energy</td>
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<td>2.4E17</td>
<td>1.0E17</td>
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<tr>
<td>N well Xj</td>
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<td>4.0#</td>
<td>3.5</td>
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<tr>
<td><strong>P well</strong></td>
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<tr>
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<tr>
<td>Energy</td>
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<td>120</td>
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<tr>
<td>Surface Conc.</td>
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<td>3.6E16</td>
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<tr>
<td>P well Xj</td>
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<td>3.1</td>
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</table>

# If Boron penetration into N-well can be eliminated with thicker photoresist
### TARGET, USL AND LSL

<table>
<thead>
<tr>
<th>Unit</th>
<th>LSL</th>
<th>Target</th>
<th>USL</th>
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<tbody>
<tr>
<td>Pad Oxide</td>
<td>Å</td>
<td>400</td>
<td>500</td>
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<tr>
<td>Nitride 1</td>
<td>Å</td>
<td>1000</td>
<td>1500</td>
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<tr>
<td>Nitride 2</td>
<td>Å</td>
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<td>4000</td>
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<tr>
<td>Gate Oxide</td>
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<tr>
<td>Poly</td>
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<td>4000</td>
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<tr>
<td>STI Depth</td>
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<tr>
<td>Poly ReOx</td>
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<tr>
<td>Trench Liner Ox</td>
<td>Å</td>
<td>400</td>
<td>500</td>
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<tr>
<td>TEOS Ox 1</td>
<td>Å</td>
<td>3500</td>
<td>4000</td>
</tr>
<tr>
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<td>Å</td>
<td>7000</td>
<td>7500</td>
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<tr>
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<td>Å</td>
<td>3500</td>
<td>4000</td>
</tr>
<tr>
<td>Metal Two</td>
<td>Å</td>
<td>7000</td>
<td>7500</td>
</tr>
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</table>
The numbers found from these hand calculations should be close to the actual values. SUPREM simulations will give more accurate results, but the hand calculations are useful for comparison and trouble shooting the simulation. Actual factory values have a target, USL and LSL due to processing variations.
REFERENCES

HOMEWORK – HANDCALC FOR ADV-CMOS

1. Why is 1E16 cm\(^{-3}\) well doping too low for this process?

2. Why is 5 volts supply too high for this process?

3. Adding another photo level will allow for separate VT adjust implants (no blanket implant). What will the VT adjust implant dose be for each transistor?