BERKELEY CMOS PROCESS

A USER GUIDE

by

W. G. Oldham, A. R. Neureuther,

Y. Shacham, and F. Dupois

Memorandum No. UCB/ERL M84/84

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ELECTRONICS RESEARCH LABORATORY

College of Engineering
University of California, Berkeley
94720

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Research sponsored by the Defense Advanced Research Projects Agency Contract No. N00039-84-C-0107, and by the Semiconductor Research Consortium Contract SRC-82-11-008.

Introduction and Initial Process Conception

PROPOSED BERKELEY CMOS PROCESS-OUTLINE

Pei-Lin Pai & Mong-Song Liang

Version 0.0 (Dec. 18 1983)

(A) WAFER PREPARATION

— *resistivity measurement*

(B) INITIAL OXIDATION

2200A; 1100°C; 10min. wet O_2

— *oxide thickness measurement*

(C) N-WELL FORMATION

1. *phototransfer <WELL MASK>*
2. *well-oxide etch*
3. *well II: Phos./80KeV/1.6 X 10^{12}*
4. *well drive-in (X_j~3µm)*
   1150°C; 10min. wet O_2 + 270min. N_2

— *oxide thickness measurement*
N-well and p-sub oxides

(D) ISOLATION

1. *all oxide etch: 3000A on well, 2500A on p-field*
2. *pad oxide growth: ~200A; 950°C 35min. O_2*

— *oxide thickness measurement*

3. *nitride deposition: ~1000A*

— *nitride thickness measurement*

4. *phototransfer <ACTV MASK>*
5. *phototransfer <FPII MASK>*
6. *field II: Boron/60KeV/1.0 X 10^{13}*
7. *field oxidation: 6100A; 950°C; 200min. wet O_2*

— *oxide thickness measurement*

8. *nitride strip*

OPTION
* *phototransfer <CAP. MASK>*
* *cap. area II: As/100KeV/1.2 X 10^{15}*

9. *pad oxide strip*

(E) *V_T II/punch through II*

1. *clean-up oxide growth: ~200A*

— *oxide thickness measurement*

2. *V_T II: Boron/30KeV/2.3X10^{12}*

OPTION
* *phototransfer <FPII MASK>*
* *n-channel punch-through II: Boron/40KeV/1.5X10^{11}*
* *phototransfer <~FPII MASK>*
* *p-channel punch-through II: phos/25KeV/1.5X10^{11}*

(F) GATE OXIDE GROWTH

1. clean-up oxide etch

2. gate oxide growth: 250A; 950° C; 45min. in 3% HCl or 1% TCA

— *oxide thickness measurement*

(G) GATE DEFINITION

1. n^+-ploysilicon deposition: ~0.4µm

— *poly-Si thickness measurement*

2. phototransfer <GATE MASK>

3. polysilicon plasma etch

(H) SOURCE/DRAIN II

1. oxidation: 800° C; 15min. wet O_2

— *oxide thickness measurement 1000A on n+poly/500A on S/D*

2. oxide etch: ~200A

3. phototransfer <NNII MASK>

4. n-channel S/D II: As/100KeV/1.2 X 10^{15}

5. drive-in: X_j~0.24µm; 925° C, 75min. N_2

6. phototransfer <PPII MASK>

8. p-channel S/D II: Boron/10KeV/1.0 X 10^{15}
BF_2/50KeV/1.0 X 10^{15}

(I) PASSIVATION

1. PSG deposition: ~0.6µm

— *PSG thickness measurement*

2. densification: 900° C; 30min. N_2

(J) CONTACT OPENING

1. phototransfer <CONT MASK>

2. Al-Si sputtering: ~0.5µm

— *Al-Si thickness measurement*

3. phototransfer <METAL MASK>

4. forming gas anneal

OPTION

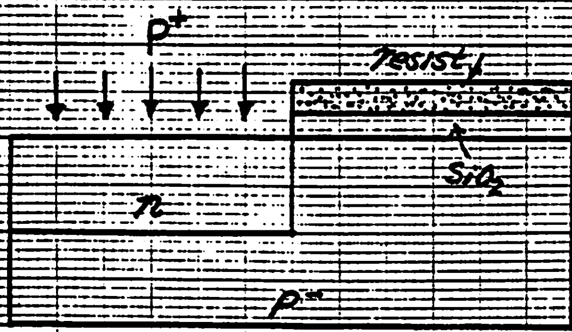
** PSG deposition: ~0.5µm*

— *PSG thickness measurement*

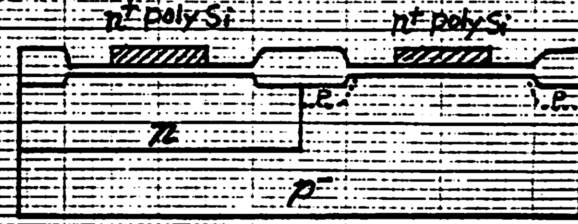
**. phototransfer <PAD MASK>*

290n-CMOS

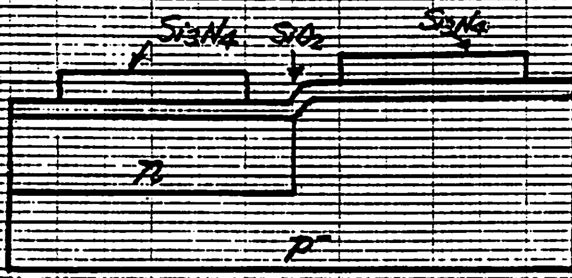
WELL II | WELL MASK



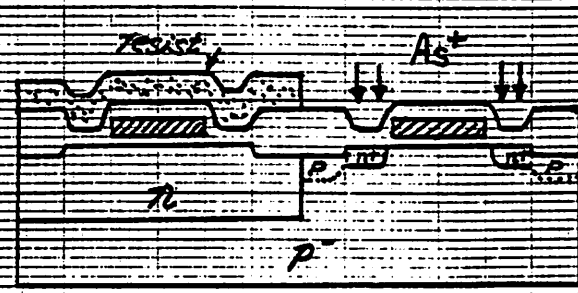
GATE MASK



ACTV MASK

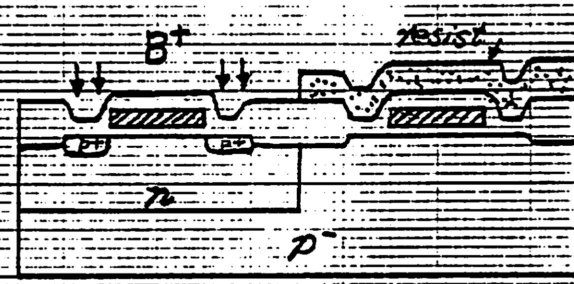


n+ S/D II | NNII MASK

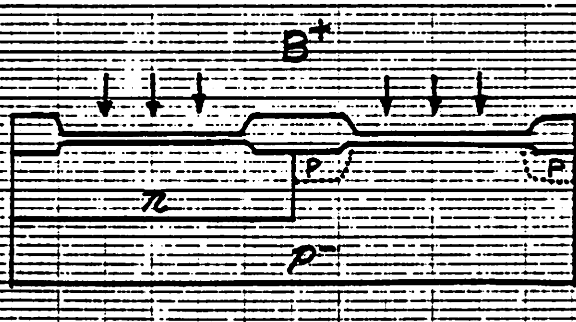


FIELD II | FPII MASK

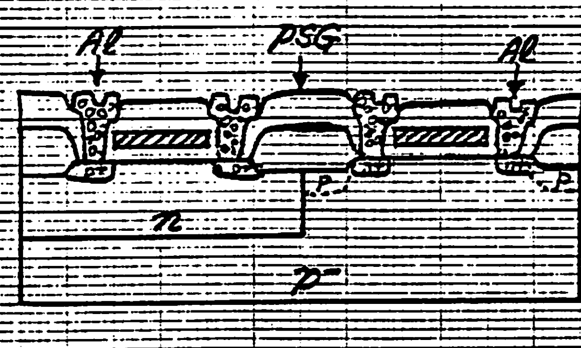
p+ S/D II | PPII MASK

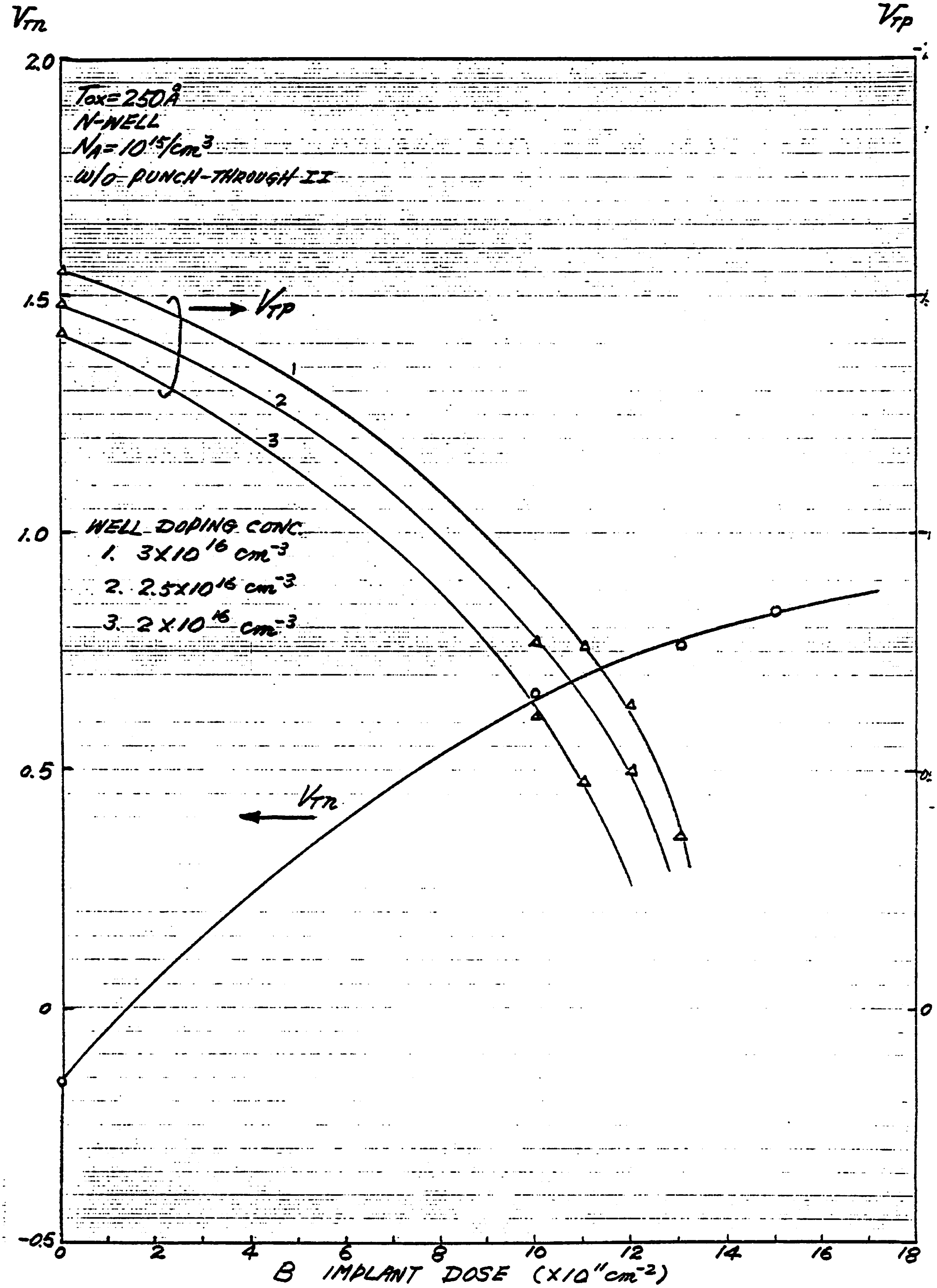


VT II

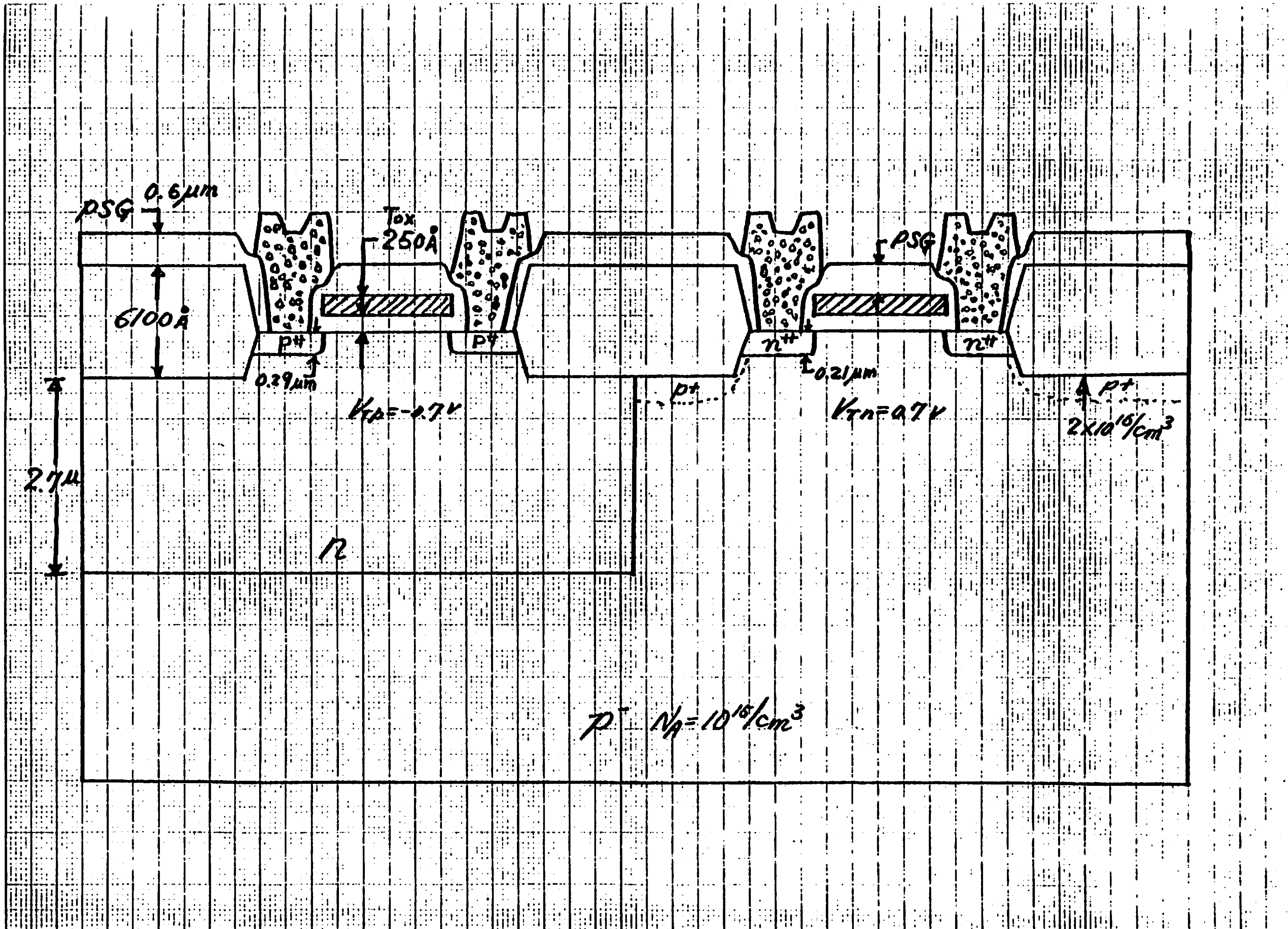


CONT MASK





V_{Tn}
V_{Tp}
2.0
1.5
1.0
0.5
0
-0.5
Tox=250Å
N-WELL
$N_A=10^{15}/cm^3$
w/o PUNCH-THROUGH II
V_{TP}
1
2
3
WELL DOPING CONC.
1. $3\times10^{16}\ cm^{-3}$
2. $2.5\times10^{16}\ cm^{-3}$
3. $2\times10^{16}\ cm^{-3}$
V_{Tn}
0
2
4
6
8
10
12
14
16
18
B IMPLANT DOSE ($\times10^{11}cm^{-2}$)


PSG
0.6μm
Tox
250Å
PSG
6100Å
p+
p+
n+
n+
0.29μm
0.21μm
p+
p+
V_{Tp}=-0.7V
V_{Tn}=0.7V
2x10^16/cm^3
2.7μ
n
p- N_A=10^15/cm^3

SUPREM Simulation For The Berkeley 1.25 μm CMOS Process

Albert T. Wu

1. Introduction

SUPREM simulation for the Berkeley 1.25 μm CMOS Process is done in a modular mode. The whole process is cut into smaller functional modules such that each key process step can be tailored separately and sequentially. The sequence for running the simulation is abbreviated in Figure 1. The output file corresponds to the input file *input* is *input.out* and the corresponding structure file is *input.st*. For files of the same level, the process parameters are correlated. Thus these files should be executed at the same level too. For example, *wellA4* and *subA1* simulates the gate oxidation step in well and substrate regions respectively. Therefore these two files should have the same gate oxidation parameters, and should run at the same level.

There are 6 final outputs. *subF2* gives the final structure for the field area in the p-substrate. *subAG2* gives the final structure for the device area under the gate in the p-substrate, i.e. the n-channel area. *subAC2* gives the final structure for the N+ drains and sources of the n-channel devices. *wellF4* gives the final structure for the field area in the well. *wellAG5* gives the final structure for the device area under the gate in the n-well, i.e. the p-channel area. *wellAC5* gives the final structure for the P+ drains and sources of the p-channel devices. These are also abbreviated in Figure 2.

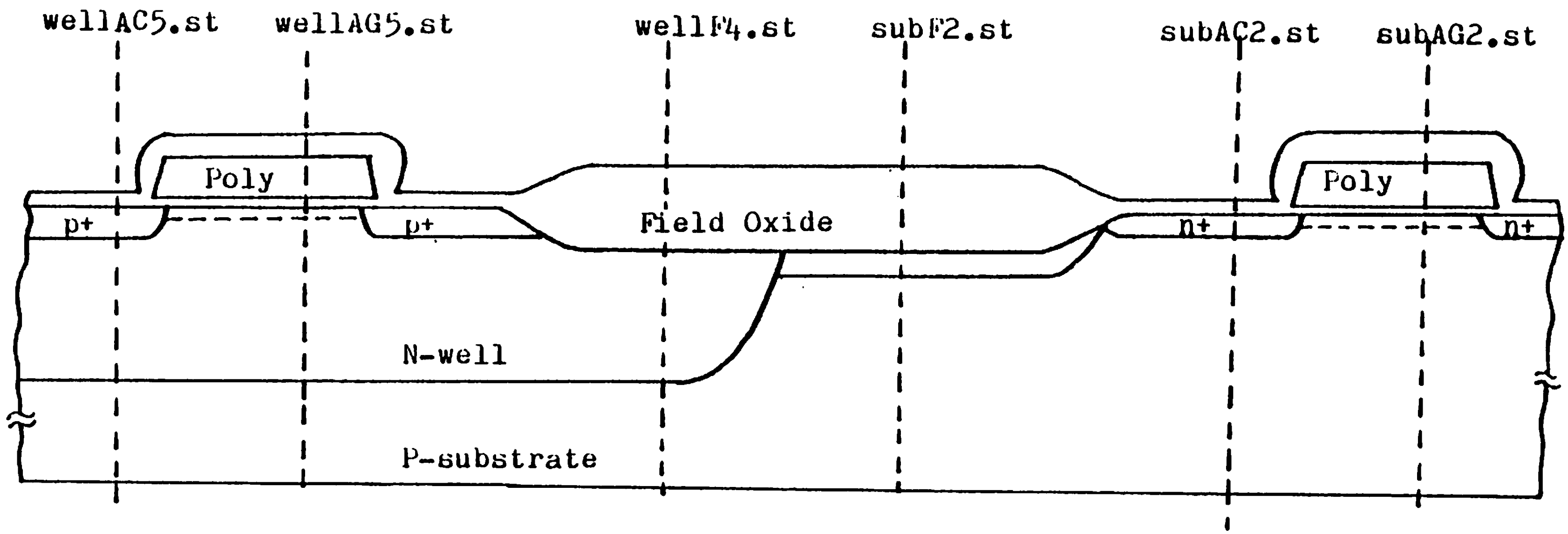


Figure 2. Regions simulated and the corresponding output structure files.

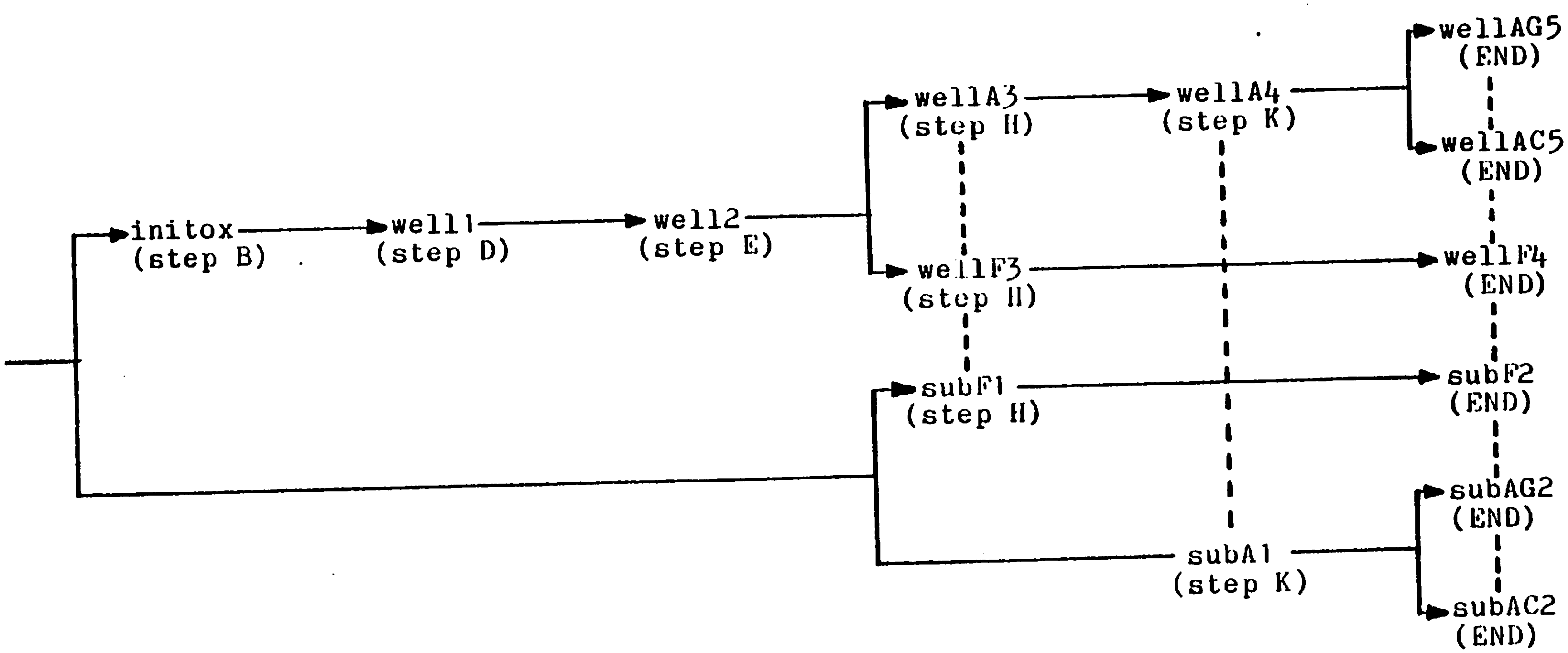


Figure 1. Input file sequence and levels for running SUPREM simulation for the Berkeley 1.25um CMOS PROCESS.

```
title       Initial Oxidation ( step B )

comment     Forms The Initial Oxide Of ~1000A
$           File : initox

comment     Initialize Silicon Substrate
$           Thickness=4.0 dx=0.04 xdx=0.0 spaces=100
$           Silicon <100> Concentration=1e15 Boron
initialize  Thickness=4.0 dx=0.04 xdx=0.0 spaces=100
+           Silicon <100> Concentration=1e15 Boron

comment     Grow Initial Oxide, 1000A
$           Temperature=1000 Time=180 DryO2
diffusion   Temperature=1000 Time=180 DryO2

comment     Print Layer Information
print       Layers

comment     Save Structure At This Point. Filename=initox.st
savefile    Name=initox.st Structure

stop        End
```

1
Initial Oxidation (step B)
Forms The Initial Oxide Of ~1000A
File : initox
Initialize Silicon Substrate
Thickness=4.0 dx=0.04 xdx=0.0 spaces=100
Silicon <100> Concentration=1e15 Boron

Grow Initial Oxide, 1000A
Temperature=1000 Time=180 DryO2

Print Layer Information

layer no.	material type	thickness (microns)	dx (microns)	dxmin (microns)	top node	bottom node	orientation or grain size
2	OXIDE	0.1037	0.0100	0.0010	399	400	
1	SILICON	3.7544	0.0400	0.0010	401	500	<100>

Integrated Dopant

layer	Net		Total	
no.	active	chemical	active	chemical
2	-8.9704e+09	-8.9704e+09	8.9704e+09	8.9704e+09
1	-3.8169e+11	-3.8169e+11	3.8169e+11	3.8169e+11
sum	-3.9066e+11	-3.9066e+11	3.9066e+11	3.9066e+11

Integrated Dopant

layer	BORON	
no.	active	chemical
2	8.9704e+09	8.9704e+09
1	3.8169e+11	3.8169e+11
sum	3.9066e+11	3.9066e+11

Junction Depths and Integrated Dopant
Concentrations for Each Diffused Region

layer no.	region no.	type	junction depth (microns)	net active Qd	total chemical Qd
2	1	p	0.	8.9704e+09	8.9704e+09
1	1	p	0.	3.8169e+11	3.8169e+11

Save Structure At This Point. Filename=initox.st

END SUPREM-III

```
title       Well Drive-in ( step D )

comment     Ion Implant And Drive-in, Well Area
$           File : well1

comment     Initialize Silicon Substrate
$           Structure=initox.st
initialize  Structure=initox.st

comment     Well Ion Implant
$           Dose=1.75e12 Energy=150 Phosphor Pearson4
implant     Dose=1.75e12 Energy=150 Phosphor Pearson4

comment     Dip Off All Oxide
etch        All oxide

comment     Well Drive-in
$           Temperature=1150 Time=240 DryO2
$           Temperature=1150 Time=40 Nitrogen
diffusion   Temperature=1150 Time=240 DryO2
diffusion   Temperature=1150 Time=40 Nitrogen

comment     Print Layer Information
print       Layers

comment     Save Structure At This Point. Filename=well1.st
savefile    Name=well1.st Structure

stop        End
```

1
Well Drive-in (step D)
Ion Implant And Drive-in, Well Area
File : well1
Initialize Silicon Substrate
Structure=initox.st

Well Ion Implant
Dose=1.75e12 Energy=150 Phosphor Pearson4

Dip Off All Oxide

Well Drive-in
Temperature=1150 Time=240 DryO2
Temperature=1150 Time=40 Nitrogen

Print Layer Information

layer no.	material type	thickness (microns)	dx (microns)	dxmin	top node	bottom node	orientation or grain size
2	OXIDE	0.3211	0.0100	0.	400	404	
1	SILICON	3.8131	0.0400	0.0010	405	500	<100>

Integrated Dopant

layer no.	Net active	Net chemical	Total active	Total chemical
2	-1.4255e+10	-1.4255e+10	3.9102e+10	3.9102e+10
1	1.2401e+12	1.2401e+12	1.9396e+12	1.9396e+12
sum	1.2259e+12	1.2259e+12	1.9787e+12	1.9787e+12

Integrated Dopant

layer no.	BORON active	BORON chemical	PHOSPHORUS active	PHOSPHORUS chemical
2	2.6679e+10	2.6679e+10	1.2423e+10	1.2423e+10
1	3.4975e+11	3.4975e+11	1.5899e+12	1.5899e+12
sum	3.7643e+11	3.7643e+11	1.6023e+12	1.6023e+12

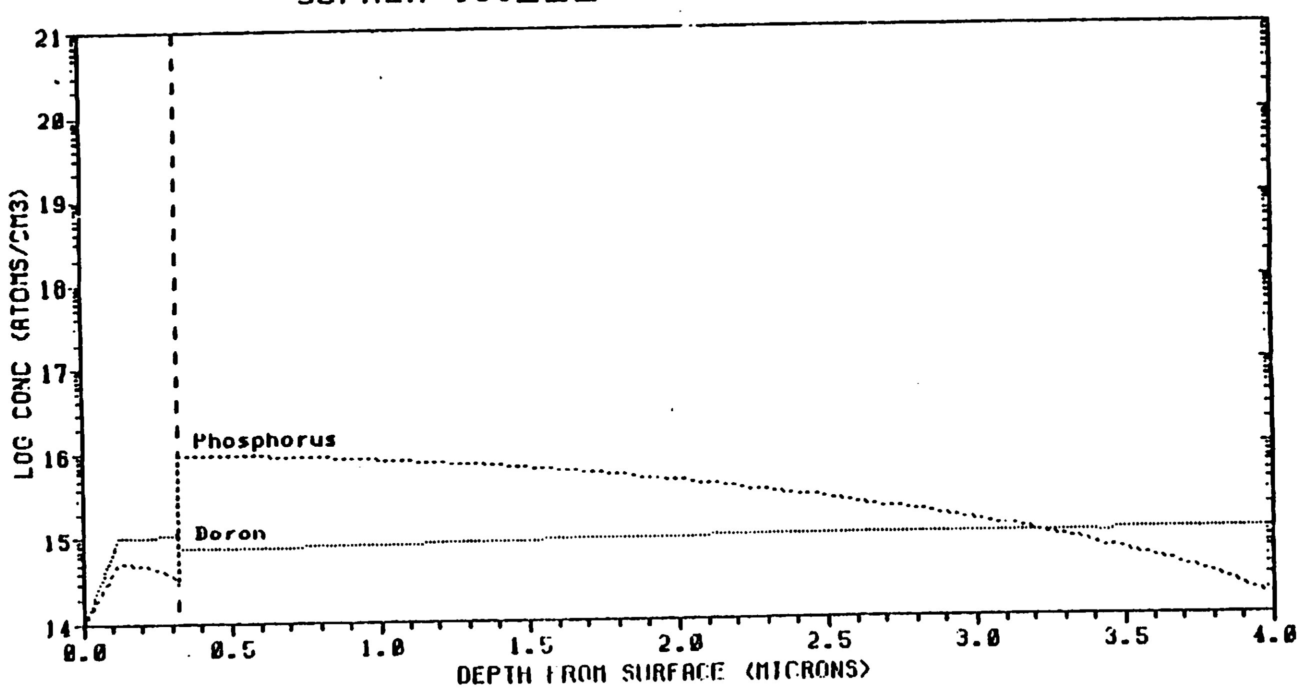
Junction Depths and Integrated Dopant
Concentrations for Each Diffused Region

layer no.	region no.	type	junction depth (microns)	net active Qd	total chemical Qd
2	2	n	0.	7.5744e+06	1.1906e+07
2	1	p	0.1224	1.1431e+10	2.9783e+10
1	2	n	0.	1.2897e+12	1.8063e+12
1	1	p	2.9331	4.9456e+10	1.2555e+11

Save Structure At This Point. Filename=well1.st

END SUPREM-III

SUPREM-III___well1



```
title        Pad Oxide Formation ( step E.2 )

comment      Pad Oxide ( ~200A ) Formation, Well Area
$            File : well2

comment      Initialize Silicon Substrate
$            Structure=well1.st
initialize   Structure=well1.st

comment      Dip Off All Surface Oxide
etch         All Oxide

comment      Change Grid Size: Layer.1 xdx=0.0 dx=0.01 Spaces=200
grid         Layer.1 xdx=0.0 dx=0.01 Spaces=200

comment      Pad Oxide Formation ( step E.2 )
$            Temperature=950 Time=28 DryO2
$            Temperature=950 Time=15 Nitrogen
diffusion    Temperature=950 Time=28 DryO2
diffusion    Temperature=950 Time=15 Nitrogen

comment      Print Layer Information
print        Layers

comment      Save Structure At This Point. Filename=well2.st
savefile     Name=well2.st Structure

stop         End
```

Jul 20 16:58 1984 well2.out Page 1

1
Pad Oxide Formation (step E.2)
Pad Oxide (~200A) Formation, Well Area
File : well2
Initialize Silicon Substrate
Structure=well1.st

Dip Off Al; Surface Oxide

Change Grid Size: Layer.1 xdx=0.0 dx=0.01 Spaces=200

Pad Oxide Formation (step E 2)
Temperature=950 Time=28 DryO2
Temperature=950 Time=15 Nitrogen

Print Layer Information

layer no.	material type	thickness (microns)	dx (microns)	dxmin	top node	bottom node	orientation or grain size
2	OXIDE	0.0187	0.0100	0.	299	300	
1	SILICON	3.8048	0.0100	0.0010	301	500	<100>

Integrated Dopant

layer no.	Net active	Net chemical	Total active	Total chemical
2	-1.5818e+09	-1.5818e+09	2.2413e+09	2.2413e+09
1	1.2428e+12	1.2428e+12	1.9345e+12	1.9345e+12
sum	1.2412e+12	1.2412e+12	1.9368e+12	1.9368e+12

Integrated Dopant

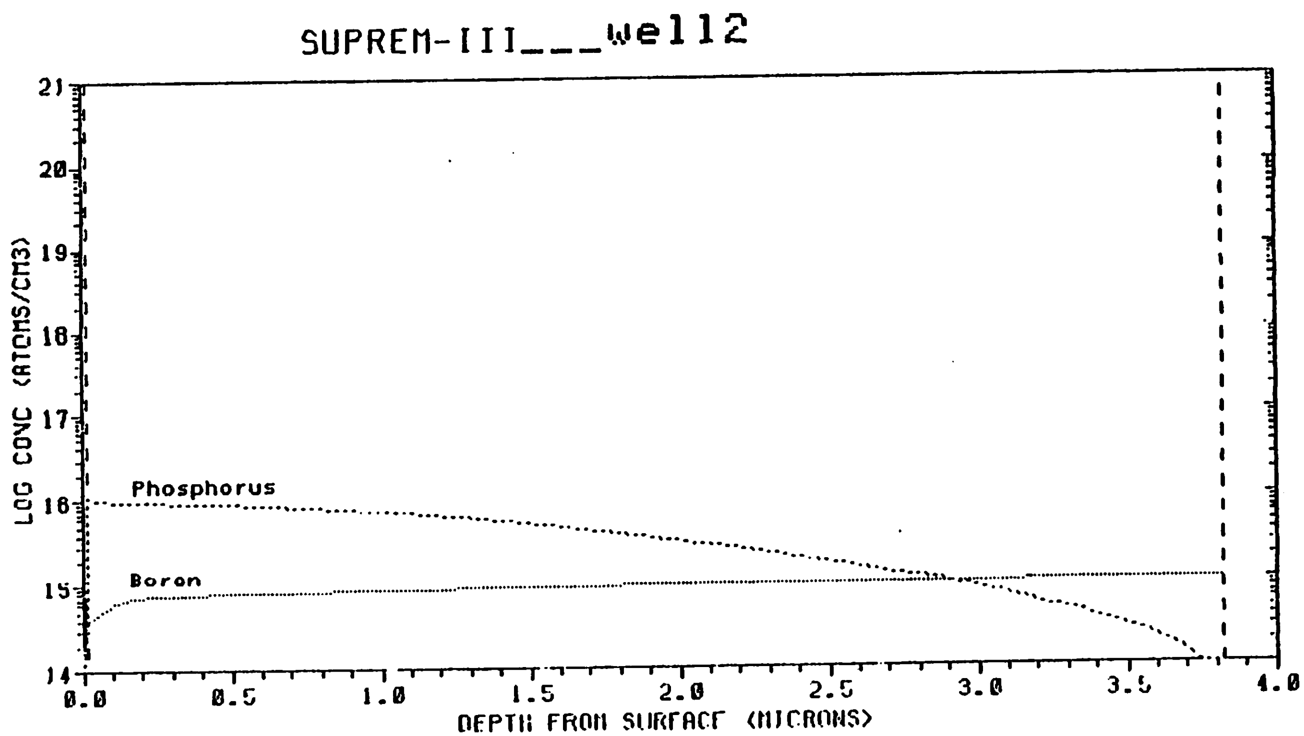
layer no.	BORON active	BORON chemical	PHOSPHORUS active	PHOSPHORUS chemical
2	1.9116e+09	1.9116e+09	3.2977e+08	3.2977e+08
1	3.4588e+11	3.4588e+11	1.5887e+12	1.5887e+12
sum	3.4779e+11	3.4779e+11	1.5890e+12	1.5890e+12

Junction Depths and Integrated Dopant
Concentrations for Each Diffused Region

layer no.	region nr.	type	junction depth (microns)	net active Qd	total chemical Qd
2	1	p	0.	1.5818e+09	2.2413e+09
1	2	n	0.	1.2923e+12	1.7991e+12
1	3	p	2.8995	4.9538e+10	1.3046e+11

Save Structure At This Point. Filename=well2.st

END SUPREM-III



SUPREM-III___well2
LOG CONC (ATOMS/CM3)
21
20
19
18
17
16
15
14
Phosphorus
Boron
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
DEPTH FROM SURFACE (MICRONS)

```
title       LOCOS, Well Region, Active Part ( step H )

comment     Nitride CVD and LOCOS for Well Region, Active Part
$           File : wellA3

comment     Initialize Silicon Substrate
$           Structure=well2.st
initialize  Structure=well2.st

comment     Deposit 1000A of CVD Nitride ( step E.3 )
$           Nitride Thickness=0.10 Spaces=15
deposition  Nitride Thickness=0.10 Spaces=15

comment     LOCOS ( step H )
$           Temperature=950 Time=5 DryO2
$           Temperature=950 Time=200 WetO2
$           Temperature=950 Time=5 DryO2
$           Temperature=950 Time=20 Nitrogen
diffusion   Temperature=950 Time=5 DryO2
diffusion   Temperature=950 Time=200 WetO2
diffusion   Temperature=950 Time=5 DryO2
diffusion   Temperature=950 Time=20 Nitrogen

comment     Print Layer Information
print       Layers

comment     Save Structure At This Point. Filename=wellA3.st
savefile    Name=wellA3.st Structure

stop        End
```

1
LOCOS, Well Region, Active Part (step H)
Nitride CVD and LOCOS for Well Region, Active Part
File : wellA3
Initialize Silicon Substrate
Structure=well2.st

Deposit 1000A of CVD Nitride (step E.3)
Nitride Thickness=0.10 Spaces=15

LOCOS (step H)
Temperature=950 Time=5 DryO2
Temperature=950 Time=200 WetO2
Temperature=950 Time=5 DryO2
Temperature=950 Time=20 Nitrogen

Print Layer Information

layer no.	material type	thickness (microns)	dx (microns)	dxmin	top node	bottom node	orientation or grain size
4	OXIDE	0.0101	0.0100	0.0010	282	283	
3	NITRIDE	0.0939	0.0100	0.0010	284	298	
2	OXIDE	0.0187	0.0100	0.	299	300	
1	SILICON	3.8048	0.0100	0.0010	301	500	<100>

Integrated Dopant

layer	Net		Total	
no.	active	chemical	active	chemical
4	0. e+00	0. e+00	0. e+00	0. e+00
3	-5.7612e+06	-5.7612e+06	2.5559e+07	2.5559e+07
2	-2.1084e+09	-2.1084e+09	2.8426e+09	2.8426e+09
1	1.2427e+12	1.2427e+12	1.9334e+12	1.9334e+12
sum	1.2406e+12	1.2406e+12	1.9362e+12	1.9362e+12

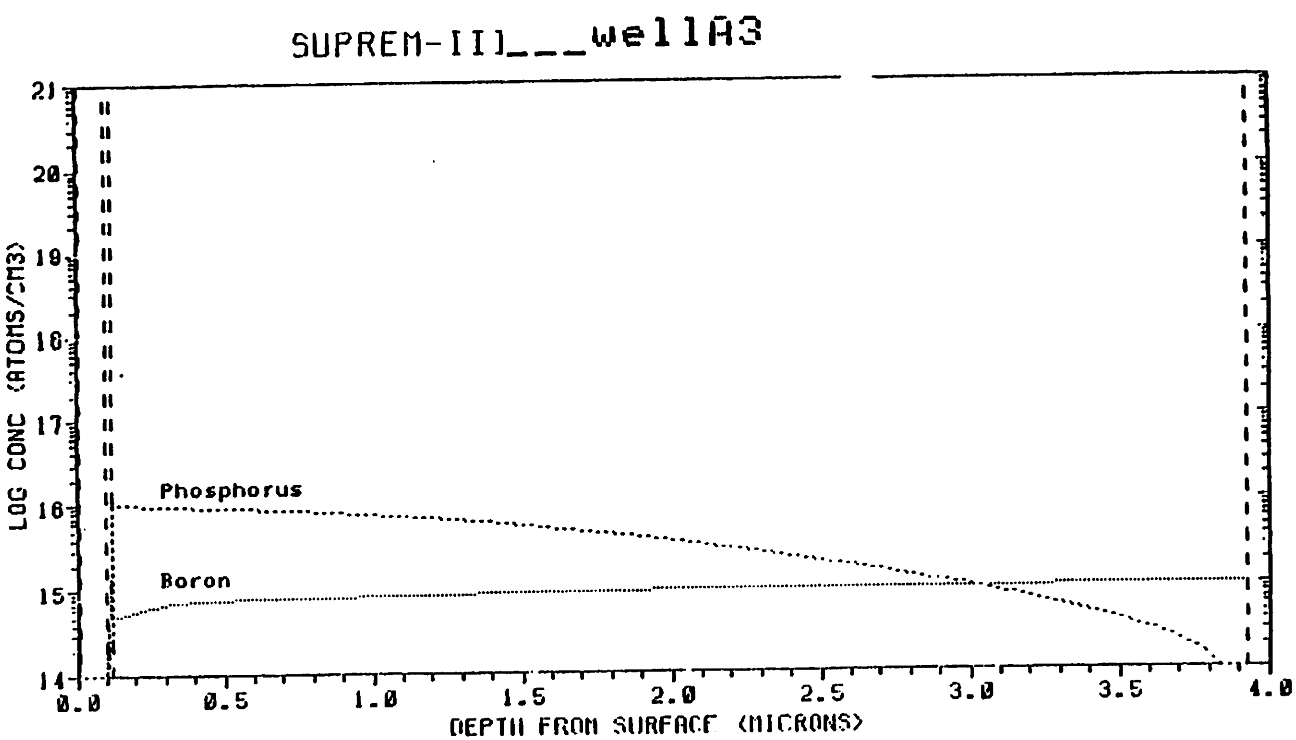
Integrated Dopant

layer	BORON		PHOSPHORUS	
no.	active	chemical	active	chemical
4	0 e+00	0. e+00	0. e+00	0. e+00
3	1.5660e+07	1.5660e+07	9.8991e+06	9.8991e+06
2	2.4755e+09	2.4755e+09	3.6711e+08	3.6711e+08
1	3.4531e+11	3.4531e+11	1.5880e+12	1.5880e+12
sum	3.4780e+11	3.4780e+11	1.5884e+12	1.5884e+12

Junction Depths and Integrated Dopant
Concentrations for Each Diffused Region

layer no	region no.	type	junction depth (microns)	net active Qd	total chemical Qd
4	[illegible]	n	0.	0. e+00	0. e+00
3	[illegible]	n	0.	0. e+00	0. e+00
3	1	p	0.0937	0. e+00	0. e+00
2	[illegible]	p	0.	2.1084e+09	2.8426e+09
1	[illegible]	n	0.	1.2921e+12	1.7978e+12
1	[illegible]	p	2.8995	4.9362e+10	1.3063e+11

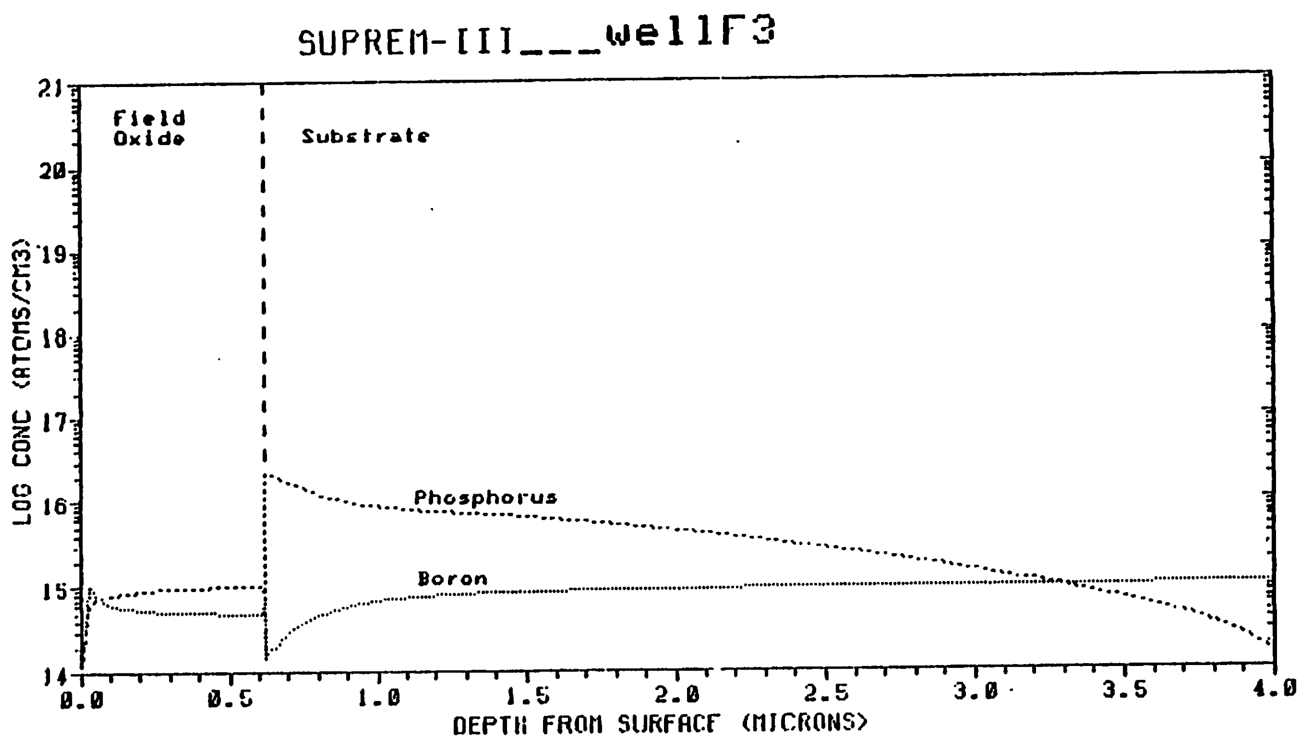
Save Structure At This Point. Filename=wellA3.st



SUPREM-III___wellA3
LOG CONC (ATOMS/CM3)
21
20
19
18
17
16
15
14
Phosphorus
Boron
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
DEPTH FROM SURFACE (MICRONS)

```
title       LOCOS, Well Region, Field Part ( step H )

comment     Heat History Up to LOCOS, Field Area in Well Region
$           File : wellF3

comment     Initialize Silicon Substrate
$           Structure=well2.st
initialize  Structure=well2.st

comment     LOCOS ( step H )
$           Temperature=950 Time=5 DryO2
$           Temperature=950 Time=200 WetO2
$           Temperature=950 Time=5 DryO2
$           Temperature=950 Time=20 Nitrogen
diffusion   Temperature=950 Time=5 DryO2
diffusion   Temperature=950 Time=200 WetO2
diffusion   Temperature=950 Time=5 DryO2
diffusion   Temperature=950 Time=20 Nitrogen

comment     Print Layer Information
print       Layers

comment     Save Structure At This Point. Filename=wellF3.st
savefile    Name=wellF3.st Structure

stop        End
```

```
1
 LOCOS, Well Region, Field Part ( step H )
 Heat History Up to LOCOS, Field Area in Well Region
 File : wellF3
 Initialize Silicon Substrate
 Structure=well2.st

 LOCOS ( step H )
 Temperature=950 Time=5 DryO2
 Temperature=950 Time=200 WetO2
 Temperature=950 Time=5 DryO2
 Temperature=950 Time=20 Nitrogen

 Print Layer Information

 layer    material type      thickness    dx     dxmin  top   bottom  orientation
  no.                        (microns)    (microns)     node   node   or grain size
   2     OXIDE                 0.6183 0.0100 0.         299    324
   1     SILICON               3.5410 0.0100 0.0010     325    500        <100>

                          Integrated Dopant
 layer              Net                            Total
  no.       active        chemical        active        chemical
   2     2.1086e+10    2.1086e+10    8.9924e+10    8.9924e+10
   1     1.2164e+12    1.2164e+12    1.8410e+12    1.8410e+12
  sum    1.2375e+12    1.2375e+12    1.9309e+12    1.9309e+12

                          Integrated Dopant
 layer             BORON                        PHOSPHORUS
  no.       active        chemical        active        chemical
   2     3.4419e+10    3.4419e+10    5.5505e+10    5.5505e+10
   1     3.1227e+11    3.1227e+11    1.5287e+12    1.5287e+12
  sum    3.4669e+11    3.4669e+11    1.5842e+12    1.5842e+12

               Junction Depths and Integrated Dopant
              Concentrations for Each Diffused Region
 layer  region  type  junction depth      net            total
  no.    no.           (microns)       active Qd      chemical Qd
   2      3      p       0.           1.1990e+09     6.6921e+09
   2      2      n       0.0790       2.2125e+10     7.9579e+10
   2      1      p       0.6183       0.    e+00     0.    e+00
   1      2      n       0.           1.2635e+12     1.7131e+12
   1      1      p       2.6960       4.7008e+10     1.2288e+11

 Save Structure At This Point. Filename=wellF3.st

 END SUPREM-III
```



SUPREM-III___wellF3
Field
Oxide
Substrate
Phosphorus
Boron
LOG CONC (ATOMS/CM3)
21
20
19
18
17
16
15
14
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
DEPTH FROM SURFACE (MICRONS)

```
title       Vt Implant, Well Region, Active Part ( step I & K )

comment     Vt Ion Implant, LOCOS for Well Region, Active Part
$           File : wellA3

comment     Initialize Silicon Substrate
comment     Structure=wellA3.st
initialize  Structure=wellA3.st

comment     Strip Sandwich Structure
etch        All Oxide
etch        All Nitride
etch        All Oxide

comment     Change Grid Size: Layer.1 xdx=0.0 dx=0.005 Spaces=399
grid        Layer.1 xdx=0.0 dx=0.005 Spaces=399

comment     Pad Oxide Growth ( step 1.1 )
$           Temperature=950 Time=28 DryO2
$           Temperature=950  Time=15 Nitrogen
diffusion   Temperature=950 Time=28 DryO2
diffusion   Temperature=950  Time=15 Nitrogen

comment     Vt Ion Implant ( step I.2 )
$           Dose=2.3e12 Energy=30 Boron Pearson4
implant     Dose=2.3e12 Energy=30 Boron Pearson4

comment     Strip Surface Oxide ( step K.2 )
etch        All Oxide

comment     Gate Oxidation ( step K.4 )****250A Oxide
$           Temperature=950 Time=45 DryO2
$           Temperature=950 Time=15 Nitrogen
diffusion   Temperature=950 Time=45 DryO2
diffusion   Temperature=950 Time=15 Nitrogen

comment     Print Lauer Information
print       Layers

comment     Save Structure At This Point. Filename=wellA4.st
savefile    Name=wellA4.st Structure

stop        End
```

1
Vt Implant, Well Region, Active Part (step I & K)
Vt Ion Implantd LOCOS for Well Region, Active Part
File : wellA3
Initialize Silicon Substrate
Structure=wellA3.st

Strip Sandwich Structure

Change Grid Size: Layer.1 xdx=0.0 dx=0.005 Spaces=399

Pad Oxide Growth (step I.1)
Temperature=950 Time=28 DryO2
Temperature=950 Time=15 Nitrogen

Vt Ion Implant (step I.2)
Dose=2.3e12 Energy=30 Boron Pearson4

Strip Surface Oxide (step K.2)

Gate Oxidation (step K.4)****250A Oxide
Temperature=950 Time=45 DryO2
Temperature=950 Time=15 Nitrogen

Print Layer Information

layer no.	material type	thickness (microns)	dx (microns)	dxmin	top node	bottom node	orientation or grain size
2	OXIDE	0.0244	0.0100	0.	102	104	
1	SILICON	3.7861	0.0050	0.0010	105	500	<100>

Integrated Dopant

layer	Net		Total	
no.	active	chemical	active	chemical
2	-3.7008e+11	-3.7008e+11	3.7118e+11	3.7118e+11
1	-3.5573e+11	-3.5573e+11	3.5265e+12	3.5265e+12
sum	-7.2581e+11	-7.2581e+11	3.8977e+12	3.8977e+12

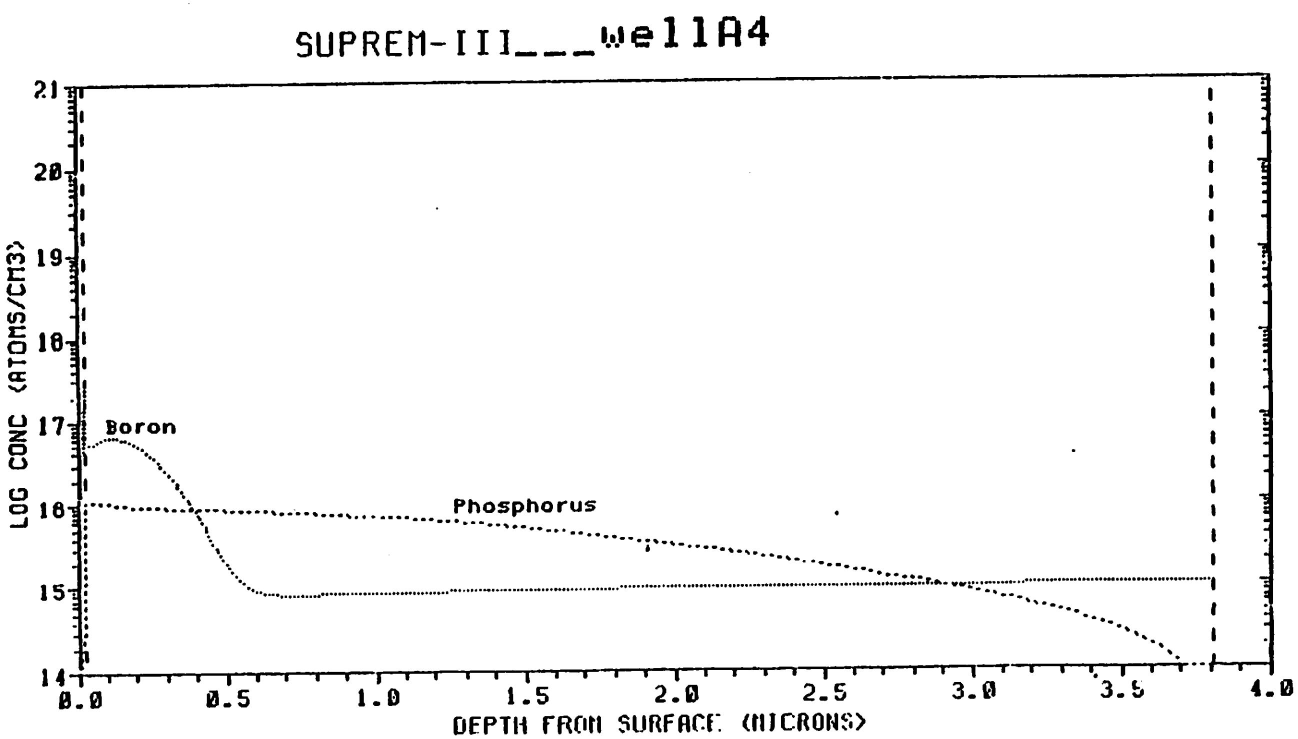
Integrated Dopant

layer	BORON		PHOSPHORUS	
no.	active	chemical	active	chemical
2	3.7063e+11	3.7063e+11	5.4906e+08	5.4906e+08
1	1.9411e+12	1.9411e+12	1.5854e+12	1.5854e+12
sum	2.3117e+12	2.3117e+12	1.5859e+12	1.5859e+12

Junction Depths and Integrated Dopant
Concentrations for Each Diffused Region

layer no.	region no.	type	junction depth (microns)	net active Qd	total chemical Qd
2	1	p	0.	3.7008e+11	3.7118e+11
1	3	p	0.	1.2105e+12	1.9265e+12
1	2	n	0.3666	9.0388e+11	1.4570e+12
1	1	p	2.8936	4.8904e+10	1.2851e+11

Save Structure At This Point. Filename=wellA4.st



SUPREM-III___wellA4
LOG CONC (ATOMS/CM3)
21
20
19
18
17
16
15
14
Boron
Phosphorus
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
DEPTH FROM SURFACE (MICRONS)

```
title       Post-LOCOS, Well Region, Field Part ( step H )

comment     Heat History After LOCOS, Field Area in Well Region.
$           File : wellF4

comment     Initialize Silicon Substrate
$           Structure=wellF3.st
initialize  Structure=wellF3.st

comment     Dip Off 250A Surface Oxide
etch        Oxide Thickness=0.0250

comment     Pad Oxide Growth ( step I.1 )
$           Temperature=950 Time=28 DryO2
$           Temperature=950  Time=15 Nitrogen
diffusion   Temperature=950 Time=28 DryO2
diffusion   Temperature=950  Time=15 Nitrogen

comment     Vt Ion Implant ( step I.2 )
$           Dose=2.3e12 Energy=30 Boron Pearson4
implant     Dose=2.3e12 Energy=30 Boron Pearson4

comment     Dip Off 275A Surface Oxide
etch        Oxide Thickness=0.0275

comment     Gate Oxidation ( step K.4 )****250A Oxide
$           Temperature=950 Time=45 DryO2
$           Temperature=950 Time=15 Nitrogen
diffusion   Temperature=950 Time=45 DryO2
diffusion   Temperature=950 Time=15 Nitrogen

comment     Blockade Oxidation ( step N )
$           Temperature=800 Time=15 WetO2
diffusion   Temperature=800 Time=15 WetO2

comment     n+ S/D Ion Implant ( step O.4 )
$           Dose=3.0e15 Energy=100 Arsenic Pearson4
implant     Dose=3.0e15 Energy=100 Arsenic Pearson4

comment     Dip Off 50A Surface Oxide ( step O.6 )
etch        Oxide Thickness=0.0050

comment     n+ S/D Drive-in ( step P )
$           Temperature=925 Time=75 DryO2
diffusion   Temperature=925 Time=75 DryO2

comment     p+ S/D Ion Implant ( step Q.4 )
$           Dose=2.0e15 Energy=10 Boron Pearson
implant     Dose=2.0e15 Energy=10 Boron Pearson

comment     Dip Off 50A Surface Oxide ( step Q.6 )
etch        Oxide Thickness=0.0050

comment     BPSG Densification ( step R.2 )
$           Temperature=950 Time=30 Nitrogen
diffusion   Temperature=950 Time=30 Nitrogen
```

```
comment    Print Layer Information
print      Layers

comment    Save Structure At This Point. Filename=wellF4.st
savefile   Name=wellF4.st Structure

stop       End of Whole Process
```

1
Post-LOCOS, Well Region, Field Part (step H)
Heat History After LOCOS, Field Area in Well Region
File : wellF4
Initialize Silicon Substrate
Structure=wellF3.st

Dip Off 250A Surface Oxide

Pad Oxide Growth (step I.1)
Temperature=950 Time=28 DryO2
Temperature=950 Time=15 Nitrogen

Vt Ion Implant (step I.2)
Dose=2.3e12 Energy=30 Boron Pearson4

Dip Off 275A Surface Oxide

Gate Oxidation (step K.4)****250A Oxide
Temperature=950 Time=45 DryO2
Temperature=950 Time=15 Nitrogen

Blockade Oxidation (step N)
Temperature=800 Time=15 WetO2

n+ S/D Ion Implant (step O.4)
Dose=3.0e15 Energy=100 Arsenic Pearson4

Dip Off 50A Surface Oxide (step O.6)

n+ S/D Drive-in (step P)
Temperature=925 Time=75 DryO2

p+ S/D Ion Implant (step Q.4)
Dose=2.0e15 Energy=10 Boron Pearson

Dip Off 50A Surface Oxide (step Q.6)

BPSG Densification (step R.2)
Temperature=950 Time=30 Nitrogen

Print Layer Information

layer no.	material type	thickness (microns)	dx (microns)	dxmin	top node	bottom node	orientation or grain size
2	OXIDE	0.5704	0.0100	0.	303	324	
1	SILICON	3.5346	0.0100	0.0010	325	500	<100>

Integrated Dopant

layer	Net		Total	
no.	active	chemical	active	chemical
2	1.0583e+15	1.0583e+15	4.2903e+15	4.2903e+15
1	1.2141e+12	1.2141e+12	1.8369e+12	1.8369e+12
sum	1.0596e+15	1.0596e+15	4.2922e+15	4.2922e+15

Integrated Dopant

layer no.	PHOSPHORUS active	PHOSPHORUS chemical	ARSENIC active	ARSENIC chemical
2	5.2680e+10	5.2680e+10	2.6743e+15	2.6743e+15
1	1.5255e+12	1.5255e+12	0. e+00	0. e+00
sum	1.5782e+12	1.5782e+12	2.6743e+15	2.6743e+15

Integrated Dopant

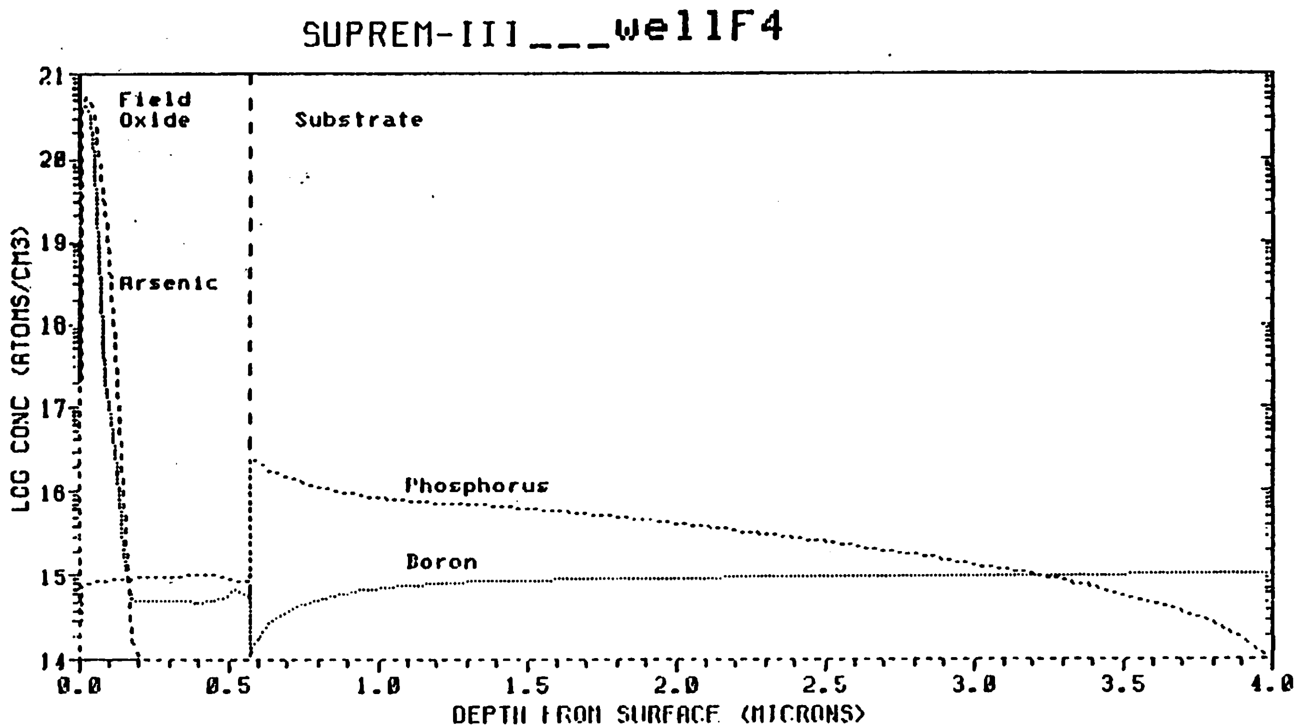
layer no.	BORON active	BORON chemical
2	1.6160e+15	1.6160e+15
1	3.1141e+11	3.1141e+11
sum	1.6163e+15	1.6163e+15

Junction Depths and Integrated Dopant
Concentrations for Each Diffused Region

layer no.	region no.	type	junction depth (microns)	net active Qd	total chemical Qd
2	2	p	0.	4.9680e+12	4.9680e+12
2	1	n	0.0100	1.0547e+15	3.8860e+15
1	2	n	0.	1.2629e+12	1.7059e+12
1	1	p	2.6544	4.8770e+10	1.2612e+11

Save Structure At This Point. Filename=wellF4.st

END SUPREM-III



SUPREM-III ___wellF4
Field
Oxide
Substrate
Arsenic
Phosphorus
Boron
LOG CONC (ATOMS/CM3)
21
20
19
18
17
16
15
14
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
DEPTH FROM SURFACE (MICRONS)

```
title       Well, Gate Area, From Poly CVD to End ( step L to R )

comment     Heat Cycle from POLY CVD to PSG Reflow, Well, Gate Region
$           File : wellAG5

comment     Initialize Silicon Substrate
$           Structure=wellA4.st
initialize  Structure=wellA4.st

comment     0.4um N+ Poly CVD ( step L )
deposition  Thickness=0.4 Polysili Temperature=650
+           Phosphor Concentr=1e20 dx=0.02

comment     Blockade Oxidation ( step N )
$           Temperature=800 Time=15 WetO2
diffusion   Temperature=800 Time=15 WetO2

comment     n+ S/D Drive-in ( step P )
$           Temperature=925 Time=75 DryO2
diffusion   Temperature=925 Time=75 DryO2

comment     p+ S/D Ion Implant ( step Q.4 )
$           Dose=2.0e15 Energy=10 Boron Pearson
implant     Dose=2.0e15 Energy=10 Boron Pearson

comment     Change The Oxide Grid Size:
$           Layer.4 xdx=0.0 dx=0.0010 Spaces=36
grid        Layer.4 xdx=0.0 dx=0.0010 Spaces=36

comment     Dip Off 50A Surface Oxide ( step Q.6 )
etch        Oxide Thickness=0.0050

comment     BPSG Densification ( step R.2 )
$           Temperature=950 Time=30 Nitrogen
diffusion   Temperature=950 Time=30 Nitrogen

comment     Print Lauer Information
print       Layers

comment     Save Structure At This Point. Filename=wellAG5.st
savefile    Name=wellAG5.st Structure

stop        End of Whole Process
```

1
Well, Gate Area, From Poly CVD to End (step L to R)
Heat Cycle from POLY CVD to PSG Reflow, Well, Gate Region
File : wellAG5
Initialize Silicon Substrate
Structure=wellA4.st

0.4um N+ Poly CVD (step L)

Blockade Oxidation (step N)
Temperature=800 Time=15 WetO2

n+ S/D Drive-in (step P)
Temperature=925 Time=75 DryO2

p+ S/D Ion Implant (step Q.4)
Dose=2.0e15 Energy=10 Boron Pearson

Change The Oxide Grid Size:
Layer.4 xdx=0.0 dx=0.0010 Spaces=36

Dip Off 50A Surface Oxide (step Q.6)

BPSG Densification (step R.2)
Temperature=950 Time=30 Nitrogen

Print Layer Information

layer no.	material type	thickness (microns)	dx (microns)	dxmin (microns)	top node	bottom node	orientation or grain size
4	OXIDE	0.0313	0.0010	0.	49	81	
3	POLYSILICON	0.3840	0.0200	0.0010	82	101	0.8069
2	OXIDE	0.0244	0.0100	0.	102	104	
1	SILICON	3.7861	0.0050	0.0010	105	500	<100>

Integrated Dopant

layer	Net		Total	
no.	active	chemical	active	chemical
4	-9.6744e+14	-9.6744e+14	9.8054e+14	9.8054e+14
3	2.2709e+15	2.8852e+15	4.4656e+15	5.0800e+15
2	3.4688e+12	3.4688e+12	4.2984e+12	4.2984e+12
1	-3.2437e+11	-3.2437e+11	3.5489e+12	3.5489e+12
sum	1.3066e+15	1.9209e+15	5.4540e+15	6.0683e+15

Integrated Dopant

layer	BORON		PHOSPHORUS	
no.	active	chemical	active	chemical
4	9.7399e+14	9.7399e+14	6.5481e+12	6.5481e+12
3	1.0974e+15	1.0974e+15	3.3682e+15	3.9826e+15
2	4.1480e+11	4.1480e+11	3.8836e+12	3.8836e+12
1	1.9366e+12	1.9366e+12	1.6122e+12	1.6122e+12
sum	2.0737e+15	2.0737e+15	3.3803e+15	3.9946e+15

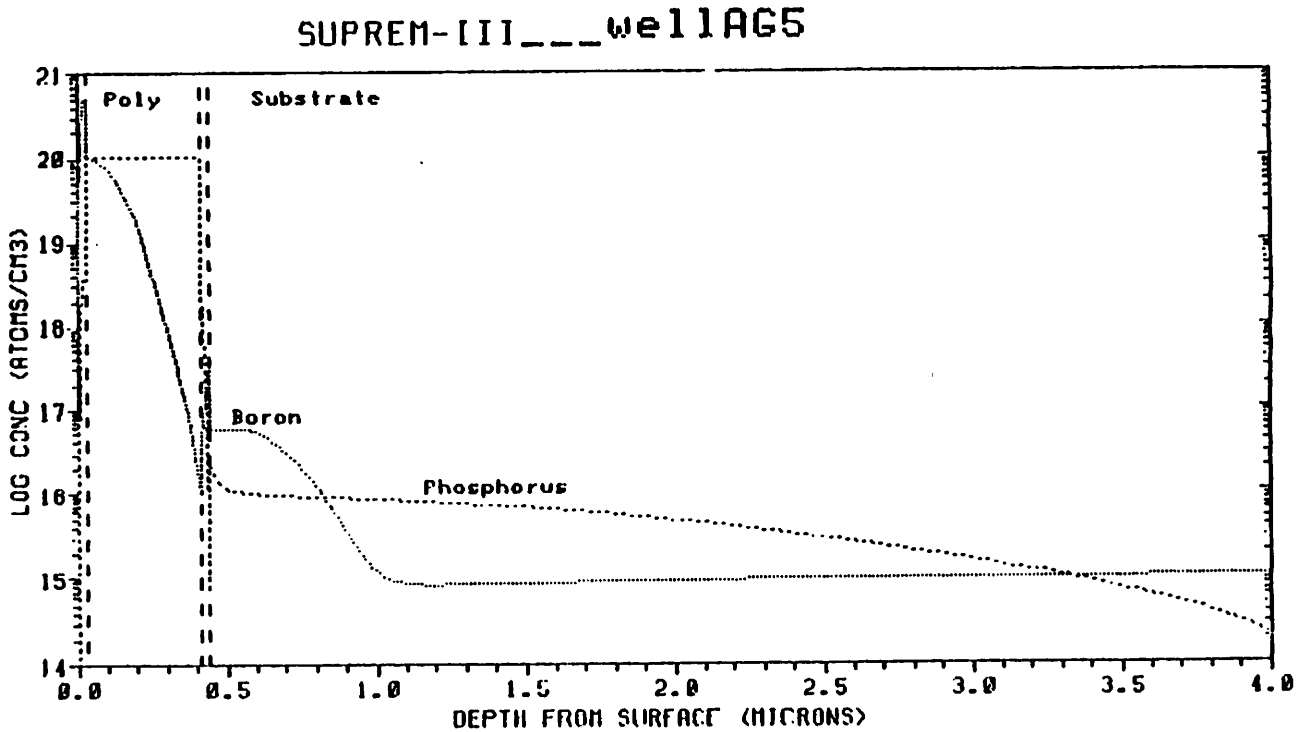
Junction Depths and Integrated Dopant
Concentrations for Each Diffused Region

layer	region	type	junction depth	net	total

no.	no.		(microns)	active Qd	chemical Qd
4	1	p	0.	9.6744e+14	9.8054e+14
3	1	n	0.	2.2709e+15	5.0800e+15
2	2	n	0.	7.3622e+12	7.5540e+12
2	1	p	0.0216	6.1028e+10	9.7446e+10
1	3	p	0.	1.1600e+12	1.9648e+12
1	2	n	0.3863	8.8456e+11	1.4411e+12
1	1	p	2.8936	4.8830e+10	1.2858e+11

Save Structure At This Point. Filename=wellAG5.st

END SUPREM-III


SUPREM-III___wellAG5
Poly
Substrate
Boron
Phosphorus
LOG CONC (ATOMS/CM3)
21
20
19
18
17
16
15
14
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
DEPTH FROM SURFACE (MICRONS)

```
title       Well, D/S Region, From Poly Etch to End ( step M to R )

comment     Heat Cycle from Poly Etch to PSG Reflow, Well, D/S Region
$           File : wellAC5

comment     Initialize Silicon Substrate
$           Structure=wellA4.st
initialize  Structure=wellA4.st

comment     ~100A Oxide Etching Due to Poly Overetching ( step M.4 )
etch        Oxide Thickness=0.0100

comment     Blockade Oxidation ( step N )
$           Temperature=800 Time=15 WetO2
diffusion   Temperature=800 Time=15 WetO2

comment     n+ S/D Drive-in ( step P )
$           Temperature=925 Time=75 DryO2
diffusion   Temperature=925 Time=75 DryO2

comment     p+ S/D Ion Implant ( step Q.4 )
$           Dose=2.0e15 Energy=10 Boron Pearson
implant     Dose=2.0e15 Energy=10 Boron Pearson

comment     Dip Off 50A Surface Oxide ( step Q.6 )
etch        Oxide Thickness=0.0050

comment     BPSG Densification ( step R.2 )
$           Temperature=950 Time=30 Nitrogen
diffusion   Temperature=950 Time=30 Nitrogen

comment     Print Layer Information
print       layers

comment     Save Structure At This Point. Filename=wellAC5.st
savefile    Name=wellAC5.st Structure

stop        End of Whole Process
```

1
Well, D/S Region, From Poly Etch to End (step M to R)
Heat Cycle from Poly Etch to PSG Reflow, Well, D/S Region
File : wellAC5
Initialize Silicon Substrate
Structure=wellA4.st

~100A Oxide Etching Due to Poly Overetching (step M.4)

Blockade Oxidation (step N)
Temperature=600 Time=15 WetO2

n+ S/D Drive-in (step P)
Temperature=925 Time=75 DryO2

p+ S/D Ion Implant (step Q.4)
Dose=2.0e15 Energy=10 Boron Pearson

Dip Off 50A Surface Oxide (step Q.6)

BPSG Densification (step R.2)
Temperature=950 Time=30 Nitrogen

Print Layer Information

layer no.	material type	thickness (microns)	dx (microns)	dxmin	top node	bottom node	orientation or grain size
2	OXIDE	0.0340	0.0100	0.	104	106	
1	SILICON	3.7753	0.0050	0.0010	107	500	<100>

Integrated Dopant

layer	Net		Total	
no.	active	chemical	active	chemical
2	-1.0395e+15	-1.0395e+15	1.0395e+15	1.0395e+15
1	-6.4799e+14	-6.4799e+14	6.5115e+14	6.5115e+14
sum	-1.6875e+15	-1.6875e+15	1.6907e+15	1.6907e+15

Integrated Dopant

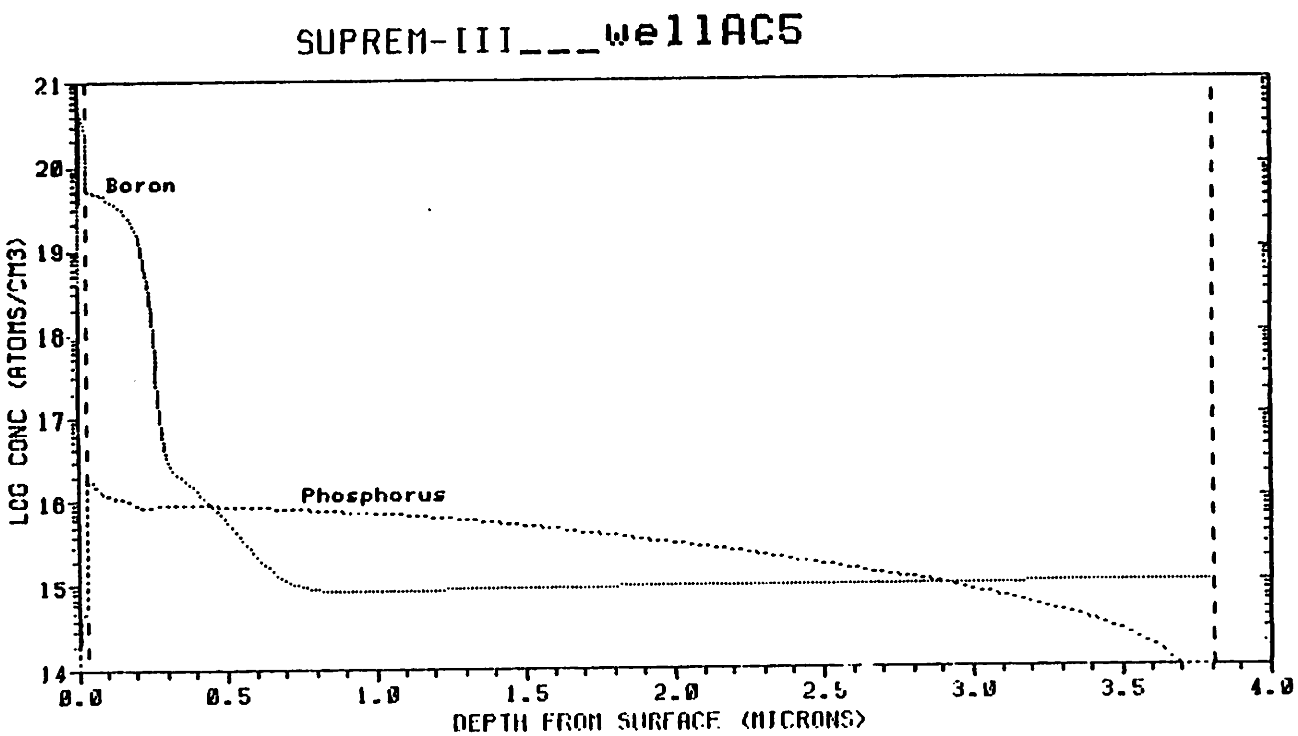
layer	BORON		PHOSPHORUS	
no.	active	chemical	active	chemical
2	1.0395e+15	1.0395e+15	1.4134e+09	1.4134e+09
1	6.4957e+14	6.4957e+14	1.5830e+12	1.5830e+12
sum	1.6891e+15	1.6891e+15	1.5844e+12	1.5844e+12

Junction Depths and Integrated Dopant
Concentrations for Each Diffused Region

layer no.	region no.	type	junction depth (microns)	net active Qd	total chemical Qd
2	4	p	0.	1.0395e+15	1.0395e+15
1	3	p	0.	6.4875e+14	6.4961e+14
1	2	n	0.4221	8.1904e+11	1.3987e+12
1	1	p	2.8703	5.0038e+10	1.2987e+11

Save Structure At This Point. Filename=wellAC5.st

END SUPREM-III



SUPREM-III___wellAC5
Boron
Phosphorus
LOG CONC (ATOMS/CM3)
21
20
19
18
17
16
15
14
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
DEPTH FROM SURFACE (MICRONS)

```
title       Field Implant, LOCOS, P-sub Region, Field Part ( step H )

comment     Field Ion Implant And LOCOS, P-substrate, Field Part
$           File : subF1

comment     Initialize Silicon Substrate
$           Thickness=2.0 dx=0.005 xdx=0.0 spaces=200
$           Silicon <100> Concentration=1e15 Boron
initialize  Thickness=2.0 dx=0.005 xdx=0.0 spaces=200
+           Silicon <100> Concentration=1e15 Boron

comment     Pad Oxide Growth ( Step E.2 )
$           Temperature=950 Time=28 DryO2
$           Temperature=950 Time=15 Nitrogen
diffusion   Temperature=950 Time=28 DryO2
diffusion   Temperature=950 Time=15 Nitrogen

comment     Field Ion Implant ( step G.4 )
$           Energy=100.0 Dose=1.0e13 Boron Pearson4
implant     Energy=100.0 Dose=1.0e13 Boron Pearson4

comment     LOCOS ( H )
$           Temperature=950 Time=5 DryO2
$           Temperature=950 Time=200 WetO2
$           Temperature=950 Time=5 DryO2
$           Temperature=950 Time=20 Nitrogen
diffusion   Temperature=950 Time=5 DryO2
diffusion   Temperature=950 Time=200 WetO2
diffusion   Temperature=950 Time=5 DryO2
diffusion   Temperature=950 Time=20 Nitrogen

comment     Print Layer Information
print       Layers

comment     Save Structure At This Point. Filename=subF1.st
savefile    Name=subF1.st Structure

stop        End
```

1
Field Implant, LOCOS, P-sub Region, Field Part (step H)
Field Ion Implant And LOCOS, P-substrate, Field Part
File : subF1
Initialize Silicon Substrate
Thickness=2.0 dx=0.005 xdx=0.0 spaces=200
Silicon <100> Concentration=1e15 Boron

Pad Oxide Growth (Step E.2)
Temperature=950 Time=28 DryO2
Temperature=950 Time=15 Nitrogen

Field Ion Implant (step G.4)
Energy=100.0 Dose=1.0e13 Boron Pearson4

LOCOS (H)
Temperature=950 Time=5 DryO2
Temperature=950 Time=200 WetO2
Temperature=950 Time=5 DryO2
Temperature=950 Time=20 Nitrogen

Print Layer Information

layer no.	material type	thickness (microns)	dx (microns)	dxmin	top node	bottom node	orientation or grain size
2	OXIDE	0.6178	0.0100	0.0010	299	344	
1	SILICON	1.7282	0.0050	0.0010	345	500	<100>

Integrated Dopant

layer	Net		Total	
no.	active	chemical	active	chemical
2	-6.7573e+12	-6.7573e+12	6.7573e+12	6.7573e+12
1	-3.4376e+12	-3.4376e+12	3.4376e+12	3.4376e+12
sum	-1.0195e+13	-1.0195e+13	1.0195e+13	1.0195e+13

Integrated Dopant

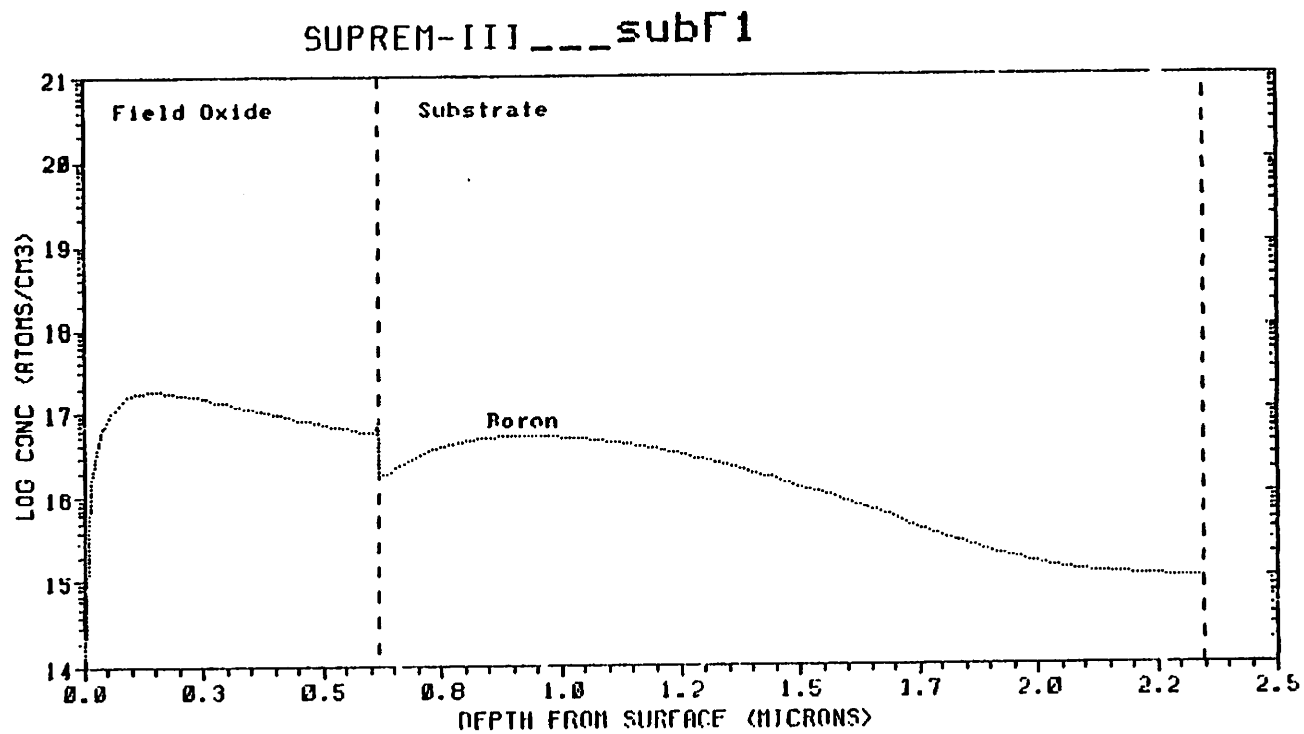
layer	BORON	
no.	active	chemical
2	6.7573e+12	6.7573e+12
1	3.4376e+12	3.4376e+12
sum	1.0195e+13	1.0195e+13

Junction Depths and Integrated Dopant
Concentrations for Each Diffused Region

layer no.	region no.	type	junction depth (microns)	net active Qd	total chemical Qd
2	1	p	0.	6.7573e+12	6.7573e+12
1	1	p	0.	3.4376e+12	3.4376e+12

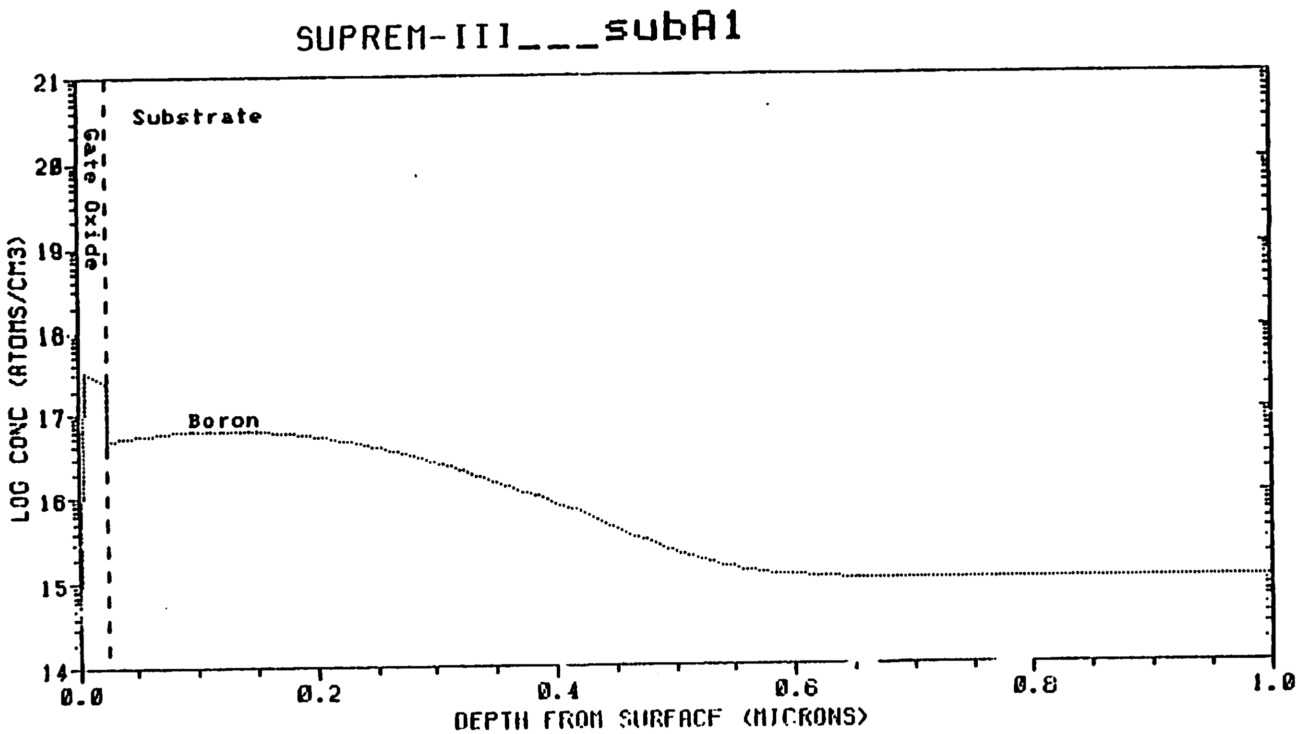
Save Structure At This Point. Filename=subF1.st

END SUPREM-III


SUPREM-III ___subF1
Field Oxide
Substrate
Boron
LOG CONC (ATOMS/CM3)
21
20
19
18
17
16
15
14
0.0
0.3
0.5
0.8
1.0
1.2
1.5
1.7
2.0
2.2
2.5
DEPTH FROM SURFACE (MICRONS)

```
title      Vt Implant, P-substrate Region, Active Part ( step I & K )

comment    Vt Ion Implant, Gate Oxidation for P-sub Region, Active Part
$          File : subA1

comment    Initialize Silicon Substrate
$          Thickness=1.0 dx=0.0025 xdx=0.0 space=200
$          Silicon <100> Concentration=1e15 Boron
initialize Thickness=1.0 dx=0.0025 xdx=0.0 space=200
+          Silicon <100> Concentration=1e15 Boron

comment    Pad Oxide ( ~200A ) Growth ( step I.1 )
$          Temperature=950 Time=28 DryO2
$          Temperature=950  Time=15 Nitrogen
diffusion  Temperature=950 Time=28 DryO2
diffusion  Temperature=950  Time=15 Nitrogen

comment    Vt Ion Implant ( step I.2 )
$          Dose=2.3e12 Energy=30 Boron Pearson4
implant    Dose=2.3e12 Energy=30 Boron Pearson4

comment    Strip Surface Oxide ( step K.2 )
etch       All Oxide

comment    Gate Oxidation ( step K.4 )****250A Oxide
$          Temperature=950 Time=45 DryO2
$          Temperature=950 Time=15 Nitrogen
diffusion  Temperature=950 Time=45 DryO2
diffusion  Temperature=950 Time=15 Nitrogen

comment    Print Layer Information
print      Layers

comment    Save Structure At This Point. Filename=subA1.st
savefile   Name=subA1.st Structure

stop       End
```

```
1
 Vt Implant, P-substrate Region, Active Part ( step 1 & K )
 Vt Ion Implant, Gate Oxidation for P-sub Region, Active Part
 File : subA1
 Initialize Silicon Substrate
 Thickness=1.0 dx=0.0025 xdx=0.0 space=200
 Silicon <100> Concentration=1e15 Boron

 Pad Oxide ( ~200A ) Growth ( step 1.1 )
 Temperature=950 Time=28 DryO2
 Temperature=950  Time=15 Nitrogen

 Vt Ion Implant ( step I.2 )
 Dose=2.3e12 Energy=30 Boron Pearson4

 Strip Surface Oxide ( step K.2 )

 Gate Oxidation ( step K.4 )****250A Oxide
 Temperature=950 Time=45 DryO2
 Temperature=950 Time=15 Nitrogen

 Print Layer Information

 layer    material type      thickness   dx     dxmin top  bottom  orientation
  no.                        (microns)   (microns)    node  node   or grain size
   2     OXIDE                 0.0249 0.0100 0.       302   306
   1     SILICON               0.9807 0.0025 0.0010   307   500       <100>

                           Integrated Dopant
 layer              Net                             Total
  no.        active         chemical         active         chemical
   2     -6.2261e+11    -6.2261e+11      6.2261e+11     6.2261e+11
   1     -1.6618e+12    -1.6618e+12      1.6618e+12     1.6618e+12
  sum    -2.2844e+12    -2.2844e+12      2.2844e+12     2.2844e+12

                           Integrated Dopant
 layer            BORON
  no.        active         chemical
   2      6.2261e+11     6.2261e+11
   1      1.6618e+12     1.6618e+12
  sum     2.2844e+12     2.2844e+12

              Junction Depths and Integrated Dopant
             Concentrations for Each Diffused Region
 layer  region  type  junction depth      net            total
  no.    no.            (microns)      active Qd      chemical Qd
   2      1      p         0.          6.2261e+11     6.2261e+11
   1      1      p         0.          1.6618e+12     1.6618e+12

 Save Structure At This Point. Filename=subA1.st

 END SUPREM-III
```


SUPREM-III___subA1
Substrate
Gate Oxide
Boron
LOG CONC (ATOMS/CM3)
21
20
19
18
17
16
15
14
0.0
0.2
0.4
0.6
0.8
1.0
DEPTH FROM SURFACE (MICRONS)

```
title       Vt Implant, Well Region, Active Part ( step I )

comment     Vt Ion Implantd LOCOS for Well Region, Active Part
$           File : subF1

comment     Initialize Silicon Substrate
$           Structure=subF1.st
initialize  Structure=subF1.st

comment     Pad Oxide Growth ( step I.1 )
$           Temperature=950 Time=28 DryO2
$           Temperature=950  Time=15 Nitrogen
diffusion   Temperature=950 Time=28 DryO2
diffusion   Temperature=950  Time=15 Nitrogen

comment     Vt Ion Implant ( step I.2 )
$           Dose=2.3e12 Energy=30 Boron Pearson4
implant     Dose=2.3e12 Energy=30 Boron Pearson4

comment     Dip Off 275A Surface Oxide
etch        Oxide Thickness=0.0275

comment     Gate Oxidation ( step K.4 )****250A Oxide
$           Temperature=950 Time=45 DryO2
$           Temperature=950 Time=15 Nitrogen
diffusion   Temperature=950 Time=45 DryO2
diffusion   Temperature=950 Time=15 Nitrogen

comment     Blockade Oxidation ( step N )
$           Temperature=800 Time=15 WetO2
diffusion   Temperature=800 Time=15 WetO2

comment     n+ S/D Ion Implant ( step O.4 )
$           Dose=3.0e15 Energy=100 Arsenic Pearson4
implant     Dose=3.0e15 Energy=100 Arsenic Pearson4

comment     Dip Off 50A Surface Oxide ( step O.6 )
etch        Oxide Thickness=0.0050

comment     n+ S/D Drive-in ( step P )
$           Temperature=925 Time=75 DryO2
diffusion   Temperature=925 Time=75 DryO2

comment     p+ S/D Ion Implant ( step Q.4 )
$           Dose=2.0e15 Energy=10 Boron Pearson
implant     Dose=2.0e15 Energy=10 Boron Pearson

comment     Dip Off 50A Surface Oxide ( step Q.6 )
etch        Oxide Thickness=0.0050

comment     BPSG Densification ( step R.2 )
$           Temperature=950 Time=30 Nitrogen
diffusion   Temperature=950 Time=30 Nitrogen

comment     Print Layer Information
print       Layers
```

```
comment     Save Structure At This Point. Filename=subF2.st
savefile    Name=subF2.st Structure

stop        End of Whole Process
```

```
1
 Vt Implant, Well Region, Active Part ( step I )
 Vt Ion Implantd LOCOS for Well Region, Active Part
 File : subF1
 Initialize Silicon Substrate
 Structure=subF1.st

 Pad Oxide Growth ( step I.1 )
 Temperature=950 Time=28 DryO2
 Temperature=950  Time=15 Nitrogen

 Vt Ion Implant ( step I.2 )
 Dose=2.3e12 Energy=30 Boron Pearson4

 Dip Off 275A Surface Oxide

 Gate Oxidation ( step K.4 )***x*250A Oxide
 Temperature=950 Time=45 DryO2
 Temperature=950 Time=15 Nitrogen

 Blockade Oxidation ( step N )
 Temperature=600 Time=15 WetO2

 n+ S/D Ion Implant ( step O.4 )
 Dose=3.0e15 Energy=100 Arsenic Pearson4

 Dip Off 50A Surface Oxide ( step O.6 )

 n+ S/D Drive-in ( step P )
 Temperature=925 Time=75 DryO2

 p+ S/D Ion Implant ( step Q.4 )
 Dose=2.0e15 Energy=10 Boron Pearson

 Dip Off 50A Surface Oxide ( step Q.6 )

 BPSG Densification ( step R.2 )

 Print Layer Information
```

layer no.	material type	thickness (microns)	dx (microns)	dxmin	top node	bottom node	orientation or grain size
2	OXIDE	0.5945	0.0100	0.0010	302	344	
1	SILICON	1.7219	0.0050	0.0010	345	500	<100>

Integrated Dopant

layer	Net		Total	
no.	active	chemical	active	chemical
2	1.0917e+15	1.0917e+15	4.4247e+15	4.4247e+15
1	-3.1477e+12	-3.1477e+12	3.1477e+12	3.1477e+12
sum	1.0886e+15	1.0886e+15	4.4279e+15	4.4279e+15

Integrated Dopant

layer	BORON		ARSENIC	
no.	active	chemical	active	chemical
2	1.6665e+15	1.6665e+15	2.7582e+15	2.7582e+15

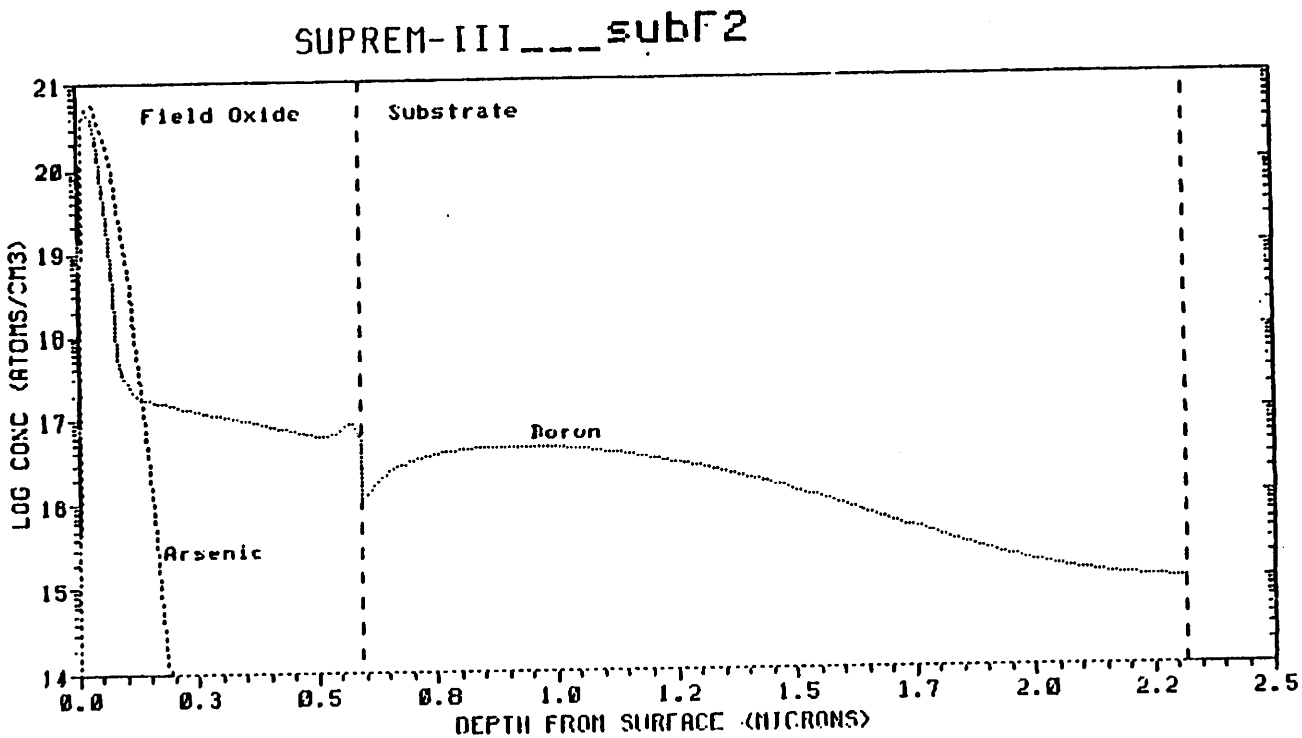
1	3.1477e+12	3.1477e+12	0. e+00	0. e+00
sum	1.6697e+15	1.6697e+15	2.7582e+15	2.7582e+15

Junction Depths and Integrated Dopant
Concentrations for Each Diffused Region

layer no.	region no.	type	junction depth (microns)	net active Qd	total chemical Qd
2	3	p	0.	9.9740e+12	3.8123e+14
2	2	n	0.0202	1.0765e+15	3.1455e+15
2	1	p	0.1458	4.3950e+12	4.4729e+12
1	1	p	0.	3.1477e+12	3.1477e+12

Save Structure At This Point. Filename=subF2.st

END SUPREM-III


SUPREM-III___subF2
Field Oxide
Substrate
Boron
Arsenic
LOG CONC (ATOMS/CM3)
21
20
19
18
17
16
15
14
0.0
0.3
0.5
0.8
1.0
1.2
1.5
1.7
2.0
2.2
2.5
DEPTH FROM SURFACE (MICRONS)

```
title      P-sub, Gate Area, From Poly CVD to End ( step L to R )

comment    Heat Cycle from POLY CVD to PSG Reflow, P-sub, Gate Region
$          File : subAG2

comment    Initialize Silicon Substrate
$          Structure=subA1.st
initialize Structure=subA1.st

comment    0.4um N+ Poly CVD ( step L )
deposition Thickness=0.4 Polysili Temperature=650
+          Phosphor Concentr=1e20 dx=0.02

comment    Blockade Oxidation ( step N )
$          Temperature=800 Time=15 WetO2
diffusion  Temperature=800 Time=15 WetO2

comment    n+ S/D Ion Implant ( step O.4 )
$          Dose=3.0e15 Energy=100 Arsenic Pearson4
implant    Dose=3.0e15 Energy=100 Arsenic Pearson4

comment    Dip Off 50A Surface Oxide ( step O.6 )
etch       Oxide Thickness=0.0050

comment    n+ S/D Drive-in ( step P )
$          Temperature=925 Time=75 DryO2
diffusion  Temperature=925 Time=75 DryO2

comment    BPSG Densification ( step R.2 )
$          Temperature=950 Time=30 Nitrogen
diffusion  Temperature=950 Time=30 Nitrogen

comment    Print Lauer Information
print      Layers

comment    Save Structure At This Point. Filename=subAG2.st
savefile   Name=subAG2.st Structure

stop       End of Whole Process
```

1
P-sub, Gate Area, From Poly CVD to End (step L to R)
Heat Cycle from POLY CVD to PSG Reflow, P-sub, Gate Region
File : subAG2
Initialize Silicon Substrate
Structure=subA1.st

0.4um N+ Poly CVD (step L)

Blockade Oxidation (step N)
Temperature=800 Time=15 WetO2

n+ S/D Ion Implant (step O.4)
Dose=3.0e15 Energy=100 Arsenic Pearson4

Dip Off 50A Surface Oxide (step O.6)

n+ S/D Drive-in (step P)
Temperature=925 Time=75 DryO2

BPSG Densification (step R.2)
Temperature=950 Time=30 Nitrogen

Print Layer Information

layer no.	material type	thickness (microns)	dx (microns)	dxmin	top node	bottom node	orientation or grain size
4	OXIDE	0.0339	0.0070	0.0010	280	281	
3	POLYSILICON	0.3829	0.0200	0.0010	282	301	0.8005
2	OXIDE	0.0249	0.0100	0.	302	306	
1	SILICON	0.9807	0.0025	0.0010	307	500	<100>

Integrated Dopant

layer no.	Net active	Net chemical	Total active	Total chemical
4	1.3020e+13	1.3020e+13	1.3020e+13	1.3020e+13
3	6.3249e+15	7.0655e+15	6.3249e+15	7.0655e+15
2	1.4970e+12	1.4970e+12	2.7580e+12	2.7580e+12
1	-1.6518e+12	-1.6518e+12	1.6529e+12	1.6529e+12
sum	6.3378e+15	7.0784e+15	6.3423e+15	7.0829e+15

Integrated Dopant

layer no.	PHOSPHORUS active	PHOSPHORUS chemical	ARSENIC active	ARSENIC chemical
4	5.9394e+12	5.9394e+12	7.0803e+12	7.0803e+12
3	3.3930e+15	4.0247e+15	2.9319e+15	3.0408e+15
2	1.7156e+12	1.7156e+12	4.1186e+11	4.1186e+11
1	5.5487e+08	5.5487e+08	4.0084e-07	4.0084e-07
sum	3.4007e+15	4.0324e+15	2.9394e+15	3.0483e+15

Integrated Dopant

layer no.	BORON active	BORON chemical
4	1.1031e+06	1.1031e+06
3	1.5310e+09	1.5310e+09
2	6.3051e+11	6.3051e+11

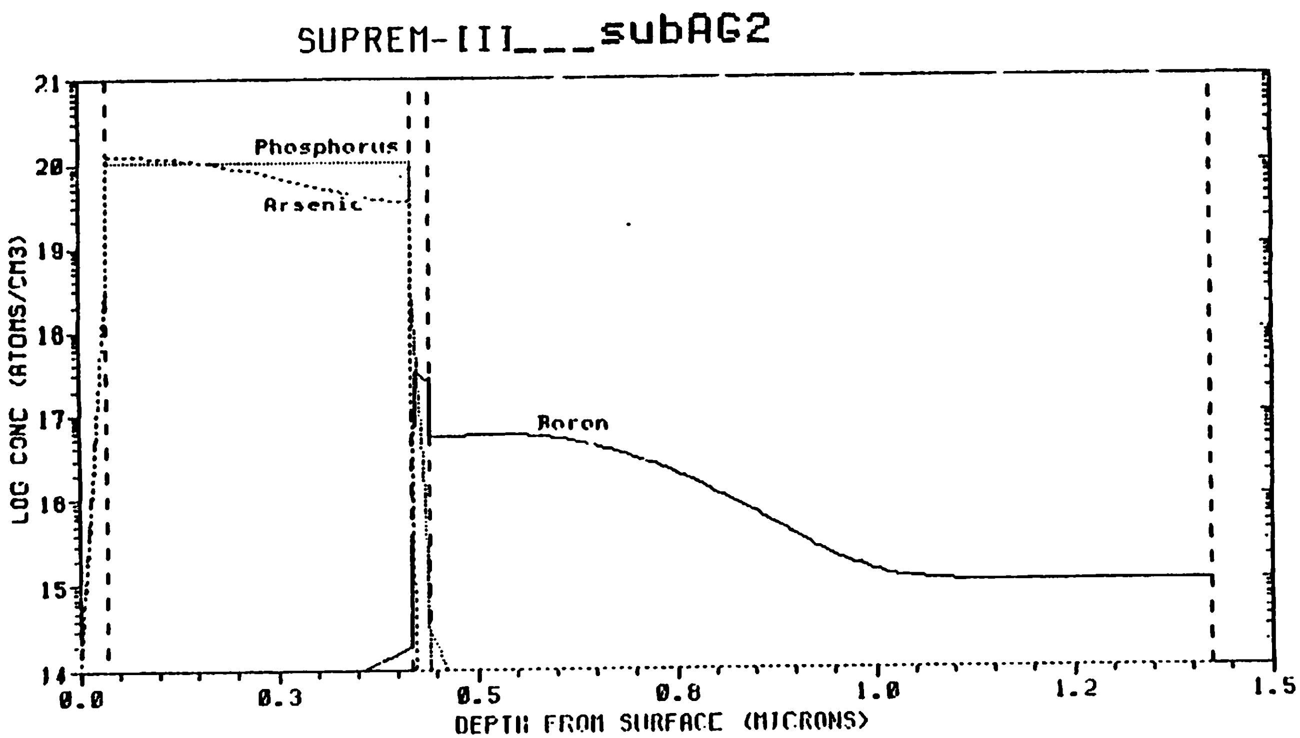
1	1.6524e+12	1.6524e+12
sum	2.2844e+12	2.2844e+12

Junction Depths and Integrated Dopant
Concentrations for Each Diffused Region

layer no.	region no.	type	junction depth (microns)	net active Qd	total chemical Qd
4	1	n	0.	1.3020e+13	1.3020e+13
3	1	n	0.	6.3249e+15	7.0655e+15
2	2	n	0.	1.7525e+12	1.9757e+12
2	1	p	0.0115	3.1360e+11	4.2849e+11
1	1	p	0.	1.6518e+12	1.6529e+12

Save Structure At This Point. Filename=subAG2.st

END SUPREM-III



SUPREM-III___subAG2
Phosphorus
Arsenic
Boron
LOG CONC (ATOMS/CM3)
21
20
19
18
17
16
15
14
0.0
0.3
0.5
0.8
1.0
1.2
1.5
DEPTH FROM SURFACE (MICRONS)

```
title       P-sub, D/S Region, From Poly Etch to End ( step M to R )

comment     Heat Cycle from Poly Etch to PSG Reflow, P-sub, D/S Region
$           File : subAC2

comment     Initialize Silicon Substrate
$           Structure=subA1.st
initialize  Structure=subA1.st

comment     Change The Oxide Grid Size
grid        Layer.2 xdx=0.0 dx=0.0010 Spaces=25

comment     ~100A Oxide Etching Due to Poly Overetching ( step M.4 )
etch        Oxide Thickness=0.0100

comment     Blockade Oxidation ( step N )
$           Temperature=800 Time=15 WetO2
diffusion   Temperature=800 Time=15 WetO2

comment     n+ S/D Ion Implant ( step O.4 )
$           Dose=3.0e15 Energy=100 Arsenic Pearson4
implant     Dose=3.0e15 Energy=100 Arsenic Pearson4

comment     Dip Off 50A Surface Oxide ( step O.6 )
etch        Oxide Thickness=0.0050

comment     n+ S/D Drive-in ( step P )
$           Temperature=925 Time=75 DryO2
diffusion   Temperature=925 Time=75 DryO2


comment     BPSG Densification ( step R.2 )
$           Temperature=950 Time=30 Nitrogen
diffusion   Temperature=950 Time=30 Nitrogen

comment     Print Layer Information
print       Layers

comment     Save Structure At This Point. Filename=subAC2.st
savefile    Name=subAC2.st Structure

stop        End of Whole Process
```

1
P-sub, D/S Region, From Poly Etch to End (step M to R)
Heat Cycle from Poly Etch to PSG Reflow, P-sub, D/S Region
File : subAC2
Initialize Silicon Substrate
Structure=subA1.st

Change The Oxide Grid Size

~100A Oxide Etching Due to Poly Overetching (step M.4)

Blockade Oxidation (step N)
Temperature=800 Time=15 WetO2

n+ S/D Ion Implant (step O.4)
Dose=3.0e15 Energy=100 Arsenic Pearson4

Dip Off 50A Surface Oxide (step O.6)

n+ S/D Drive-in (step P)
Temperature=925 Time=75 DryO2

BPSG Densification (step R.2)
Temperature=950 Time=30 Nitrogen

Print Layer Information

layer no.	material type	thickness (microns)	dx (microns)	dxmin	top node	bottom node	orientation or grain size
2	OXIDE	0.0654	0.0010	0.	296	315	
1	SILICON	0.7562	0.0025	0.0010	316	500	<100>

Integrated Dopant

layer	Net		Total	
no.	active	chemical	active	chemical
2	7.4333e+13	7.4333e+13	7.5214e+13	7.5214e+13
1	2.4746e+15	2.9430e+15	2.4775e+15	2.9459e+15
sum	2.5490e+15	3.0173e+15	2.5527e+15	3.0211e+15

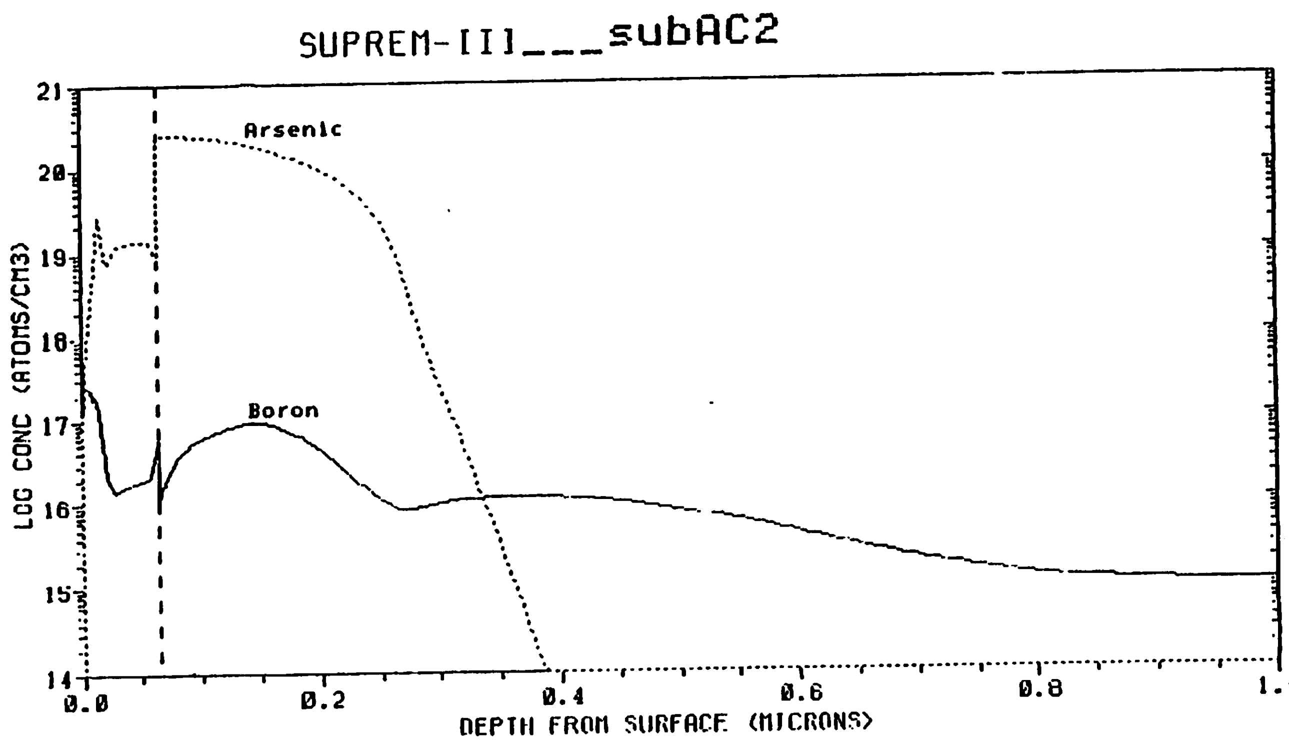
Integrated Dopant

layer	BORON		ARSENIC	
no.	active	chemical	active	chemical
2	4.4044e+11	4.4044e+11	7.4774e+13	7.4774e+13
1	1.4260e+12	1.4260e+12	2.4761e+15	2.9444e+15
sum	1.8665e+12	1.8665e+12	2.5508e+15	3.0192e+15

Junction Depths and Integrated Dopant
Concentrations for Each Diffused Region

layer no.	region no.	type	junction depth (microns)	net active Qd	total chemical Qd
2	2	p	0.	1.2413e+10	5.5723e+10
2	1	n	0.0033	7.4339e+13	7.5091e+13
1	2	n	0.	2.4749e+15	2.9455e+15
1	1	p	0.2724	2.9645e+11	3.1812e+11

Save Structure At This Point. Filename=subAC2.st


SUPREM-II]___subAC2
Arsenic
Boron
LOG CONC (ATOMS/CM3)
21
20
19
18
17
16
15
14
0.0
0.2
0.4
0.6
0.8
1.0
DEPTH FROM SURFACE (MICRONS)

100mm BERKELEY CMOS PROCESS

Documented by: C-P J. Tzeng

I-C Chen, B. Childers, M.J. Chin, F. Dupuis, J. Lee, S. Lester,
M-S Liang, P-L Pai, J.R. Pierret, Yosi Shacham, R.L. Spickelmier,
K-Y Toh, C-P J. Tzeng, A. T-T. Wu, W.G. Oldham, A.R. Neureuther

Version 1.0 (May 17, 1984) *

I. START

A. WAFER PREPARATION

{goal}: prepare clean wafers

A.0. transfer new wafers from original container to process container under laminar flow

A.1. collimated light lamp inspection

[equipment]: collimated light

reject wafers with more than 10 particles

II. WELL FORMATION

B. INITIAL OXIDATION

{goal}: denude surface of oxygen, initiate bulk precipitation of oxygen and grow 1000A oxide

B.0. [[*MOD 12*]]†: standard furnace cleaning procedure

<<Note>>: do not put wafer in the furnace in this module

[equipment]: TYLAN, bank 1, tube 2 (backup: tube 3)

[program]:TCACLEN1

B.1. oxidation: 1000 A oxide

[equipment]: TYLAN, bank 1, tube 1

[[*MOD 16*]]: standard TYLAN operation module

[program]: INITOX1

(a) load at 750° C (N_2/O_2=5/1)
(b) max ramp up to 1150° C (N_2)
(c) 1150° C, 2 hours (N_2)
(d) max ramp down to 650° C (N_2)
(e) slow ramp (2° C/min) up to 1000° C (N_2)
(f) oxidation, 1000° C, 320 min.(O_2)
(g) annealing, 1000° C, 20 min. (N_2)
(h) ramp down to 750° C (N_2)
(i) pull at 750° C (N_2/O_2=5/1)

<<Note>>: immediate coating with photoresist (C.1)

C. PHOTO-TRANSFER 1 <WELL MASK>

{goal}: transfer well pattern and perform well implantation

C.1. [[*MOD 8*]]: KODAK 820 photolithography procedure

[equipment]: Eaton and GCA

[mask]: <WELL MASK>

C.2. [[*MOD 10*]]: standard de-scum procedure

[equipment]: Technics plasma asher

C.3. [[*MOD 11*]]: standard pre-implantation bake procedure

---

* numbers subject to change

† [[*MOD 12*]] indicates module 12, details in "STANDARD PROCESS MODULES"

C.4. WELL IMPLANTATION
[equipment]: IONA ion implanter
(a) Phos. 150Kev/1.75 x 10^{12} *
C.5. oxide etching
[equipment]: wet bench 5 (in yellow room)
(a) DI H_2O, 20 sec.
(b) buffered HF, 80 sec.
(c) water bead test
(d) [[*MOD 1*]]: standard rinse-spin procedure
C.6. inspection
[equipment]: microscope in yellow room
C.7. [[*MOD 4*]]: standard resist stripping procedure

D. WELL DRIVE-IN
{goal}: form 3 μm deep n-wells, n-well oxide=3000A, p-sub oxide=3200A
D.0. [[*MOD 12*]]: standard furnace cleaning procedure
<<Note>>: do not put wafer in the furnace in this module
[equipment]: TYLAN, bank 1, tube 2 (tube 3 as backup)
[program]:TCACLEN2
D.1. well drive-in
[equipment]: TYLAN, bank 1, tube 2 (tube 3 as backup)
[[*MOD 16*]]: standard TYLAN operation module
[program]:WELLDR2
(a) load at 750° C (N_2/O_2=5/1)
(b) dry oxidation, 1150° C, 240 min.(O_2)
(c) anneal, 1150° C, 40 min.(N_2)
(d) pull at 750° C (N_2/O_2=5/1)

III. ISOLATION FORMATION
E. MASKING SANDWICH FORMATION
{goal}: form nitride, oxide, and silicon sandwich
E.0. [[*MOD 12*]]: standard furnace cleaning procedure
<<Note>>: do not put wafer in the furnace in this module
[equipment]: TYLAN, bank 1, tube 2 (tube 3 as backup)
[program]:TCACLEN2
E.1. oxide removal: all surface oxide
[equipment]: wet bench 1
(a) H_2O/HF=10/1, 10min.(Perform water bead test)
(b) [[*MOD 1*]]: standard rinse-spin procedure
E.2. pad-oxide growth: 200 A
[equipment]: TYLAN, bank 1, tube 2
[[*MOD 16*]]: standard TYLAN operation module
[program]:PADOX5
(a) push in 10% O2, 90% N2 at 750 C
(b) ramp up temperature to 950 C in 20 min.
(c) oxidize in dry O2 - 4 lpm 28 min. at 950 C
(d) anneal in N2 - 4 lpm 15 min.
(e) ramp down temperature to 750 C in 25 min.
E.3. nitride deposition: 1000 A
[equipment]: TYLAN, bank 3, tube 9
[[*MOD 16*]]: standard TYLAN operation module
[program]: SI3N49
time:16 min.
pressure: 300 mtorr
temperature: 800 C

gas flow: NH3= 25
SiH2Cl2= 75

<<Note>>: immediate move to next step recommended

F. PHOTO-TRANSFER 2 <ACTV MASK>
{goal}: transfer ACTV pattern
F.1. [[*MOD 8*]]: KODAK 820 photolithography procedure
[equipment]: Eaton and GCA
[mask]: <ACTV MASK>
F.2. [[*MOD 10*]]: standard de-scum procedure
[equipment]: Technics plasma asher
F.3. [[*MOD 14*]]: standard post-bake procedure

F.4. NITRIDE PLASMA ETCHING
[equipment]: Lam AutoEtch 480
[[*MOD 15*]]: standard LAM operation module
[program]: NITRIDE
pressure: 250 mtorr
RF power: 100 watts
gap: 1 cm
oxygen: 15 sccm
SF6: 100 sccm
time: 1 min. 50 sec.
etching rate = 700 A/min. after first 7 sec.
<<Note>>: immediate move to next step recommended

G. PHOTO-TRANSFER 3 <FPII MASK>
{goal}: transfer FPII pattern and perform field implantation and double resist
G.1. [[*MOD 8*]]: Kodak 820 photolithography procedure
[equipment]: Eaton and GCA
G.2. [[*MOD 10*]]: standard de-scum procedure
[equipment]: Technics plasma asher
G.3. [[*MOD 11*]]: standard pre-implantation bake procedure

G.4. FIELD ION IMPLANTATION
[equipment]: IONA ion implanter
(a) Boron/100 KeV/1.0 x 10^{13}
G.5. [[*MOD 5*]]: Nophenol 922 photoresist stripping procedure

H. LOCOS OXIDATION
{goal}: grow 6500 A oxide in field areas
H.0. [[*MOD 12*]]: standard furnace cleaning procedure
<<Note>>: do not put wafer in the furnace in this module
[equipment]: TYLAN, bank 1, tube 2 (tube 3 as backup)
[program]:TCACLEN2
H.1. [[*MOD 9*]]: standard oxide dip procedure
[equipment]: wet bench 1
H.2. field oxidation: 6500 A
[equipment]: TYLAN, bank 1, tube 2 (tube 3 as backup)
[[*MOD 16*]]: standard TYLAN operation module
[program]:FIEOX3
(a) push at 750 C
(b) wet oxidation, 950 C, 200 minutes
(c) post oxidation, 950 C, 5 minutes (O2/N2=1/1,

steam=off)
(d) annealing, 950 C, 20 minutes (N2)
H.3. [[*MOD 9*]]: standard oxide dip procedure (250 A, 2 min)
H.4. nitride removal: all nitride
[equipment]:
(a) H_3PO_4, 155° C, 40 min.
(b) [[*MOD 1*]]: standard rinse-spin procedure
H.5. [[*MOD 9*]]: standard oxide dip procedure
(250 A, 75 sec.)

IV. THRESHOLD ADJUSTMENT
I. THRESHOLD ADJUSTMENT
{goal}: adjust threshold voltage (V_{tn} =0.8, V_{tp} =-0.8)
I.1. pad oxide growth: 200 A
[equipment]: TYLAN, bank 1, tube 1
[[*MOD 16*]]: standard TYLAN operation module
[program]:PADOX5
(a) push in 10% O2, 90% N2 at 750 C
(b) ramp up temperature to 950 C in 20 min.
(c) oxidize in dry O2 - 4 lpm 28 min. at 950 C
(d) anneal in N2 - 4 lpm 15 min.
(e) ramp down temperature to 750 C in 25 min.
I.2. THRESHOLD ADJUSTMENT IMPLANTATION
[equipment]: IONA ion implanter
Boron/30 KeV/2.3 x 10^{12}

V. PROCESS OPTIONS FOR ANALOG
J. PHOTO-MASKING <CAP MASK>
{goal}: transfer CAP pattern and perform capacitor implantation
J.1. [[*MOD 7*]]: standard photolithography procedure
[equipment]: Eaton snd GCA
[mask]: <NNII MASK>
J.2. [[*MOD 10*]]: standard de-scum procedure
[equipment]: Technics plasma asher
J.3. [[*MOD 11*]]: standard pre-implantation bake procedure

J.4. CAPACITOR IMPLANTATION
[equipment]: IONA ion implanter
(a) As/100KeV/2.0x10^{15} *
J.5. [[*MOD 6a*]]: Plasma ashing procedure

VI. GATE/POLY FORMATION
K. GATE OXIDE GROWTH
{goal}: grow 250A oxide
K.0. [[*MOD 12*]]: standard furnace cleaning procedure
<<Note>>: do not put wafer in the furnace in this module
[equipment]: TYLAN, bank 1, tube 5
[program]:TCACLEN5
K.1. [[*MOD 2*]]: standard pirahna cleaning procedure
K.2. [[*MOD 9*]]: standard oxide dip procedure
(275 A, 85 sec.)
<<Note>>: perform 20% overdip to remove thin oxide completely
K.3. check whether poly deposition furnace is ready
K.4. gate oxidation : 250 A
<<Note>>: Do the following steps to poly deposition

[equipment]: TYLAN, bank 2, tube 6
[[*MOD 16*]]: standard TYLAN operation module
[program]:GATEOX2
(a) push in 10% O2, 90% N2 at 750 C
(b) ramp up temperature to 950 C in 20 min.
(c) purge tube with O2, 4 lpm for 5 min.
(d) oxidize in dry O2 - 4 lpm with TCA (200 sccm) for 26 min. at 950 C
(e) anneal in N2 - 4 lpm 15 min.
(f) ramp down temperature to 750 C in 25 min.

K.5. optional backside gettering preparation
(a) coat photoresist KODAK 820 on gate oxide and bake
(b) buffer HF till wafer beads on backside
(c) [[MOD 4]] standard resist stripping procedure

L. POLY DEPOSITION
{goal}: deposit 0.4 μm polysilicon
L.1. N+ poly deposition
[equipment]: TYLAN, bank 3, tube 11
[[*MOD 16*]]: standard TYLAN operation module

[program]: DOPOLY1
(a) pull in at 650 C and evacuate the tube
(b) stablize the temperature to 650 C
(c) flush PH3 gas line with 1 sccm for 2 min.
(d) deposit poly for 3 hours 15 min.
SiH4 = 100 sccm
(e) backfill the tube with 1000 sccm N2
(f) pull out the boat
<<Note>>: immediate move to next step recommended

M. PHOTO-TRANSFER 4 <GATE MASK>
{goal}: transfer gate/poly pattern
M.1. [[*MOD 7*]]: standard photolithography procedure
[equipment]: Eaton and GCA
[mask]: <GATE MASK>
M.2. [[*MOD 10*]]: standard de-scum procedure
[equipment]: Technics plasma asher
M.3. [[*MOD 14*]]: standard post-bake procedure

M.4. POLY ETCHING
{goal}: to etch 0.4 microns polysilicon plus 40 % overetch
[equipment]: Lam etcher
[program]: POLYETCH

Pressure 240	mtorr
RF PWR	300Watts
Gap	1.0cm
CCL4	95sccm
Helium	75sccm
time	01:55 min:sec.

<<NOTE>>:
(a) always run a dummy wafer before your wafers.
(b) etching rate is 3780 A/min. after the first 15 sec.

(c) poly-Si/oxide selectivity is 9.4 for blank wafers
(d) loading effect can be very significant

M.5. [[*MOD 5*]]: Nophenol 922 photoresist stripping procedure

VII. SOURCE/DRAIN FORMATION

N. BLOCKADE OXIDATION

{goal}: grow blocking oxide 800 A on poly and 300 A on S/D to stop ion implantation into poly and protect gate edges

N.0. [[*MOD 12*]]: standard furnace cleaning procedure
<<Note>>: do not put wafer in the furnace in this module
[equipment]: TYLAN, bank 1, tube 3 (tube 2 as backup)
[program]:TCACLEN3

N.1. oxide growth: 800A on poly, 300A on S/D
[equipment]: TYLAN, bank 1, tube 3 (tube 2 as backup)
[[*MOD 16*]]: standard TYLAN operation module
[program]:SPACER3
(a) 800° C, 15 min., wet oxidation
(b) anneal N2 , 20 min.

O. PHOTO-MASKING 5 <NNII MASK>

{goal}: transfer NNII pattern and perform n+ S/D implantation

O.1. [[*MOD 7*]]: standard photolithography procedure
[equipment]: Eaton snd GCA
[mask]: <NNII MASK>

O.2. [[*MOD 10*]]: standard de-scum procedure
[equipment]: Technics plasma asher

O.3. [[*MOD 11*]]: standard pre-implantation bake procedure

O.4. N+ S/D IMPLANTATION

[equipment]: IONA ion implanter
(a) As/100KeV/3.0x10^{15} *

O.5. [[*MOD 6a*]]: Plasma Ashing Procedure

O.6. [[*MOD 9*]]: standard oxide dip procedure(50 A)
[equipment]: wet bench 1

O.7. Oxide thickness measurement
250 A on n+ S/D

P. N+ S/D DRIVE-IN

{goal}: drive N+ D/S junction to 3.36 μm *

P.0. [[*MOD 12*]]: standard furnace cleaning procedure
<<Note>>: do not put wafer in the furnace in this module
[equipment]: TYLAN, bank 1, tube 3 (tube 2 as backup)
[program]: TCACLEN3

P.1. drive-in
[equipment]: TYLAN, bank 1, tube 3 (tube 2 as backup)
[[*MOD 16*]]: standard TYLAN operation module
[program]: N+S/D
(a) load at 750 C (N2/O2 = 10/1)
(b) drive-in at 925 C, 75 minutes (N2/O2=1/2)
(c) pull at 750 C
<<Note>>: immediate move to next step recommended

Q. PHOTO-MASKING 6 <PPII>

{goal}: transfer PPII pattern and perform p+ S/D implantation

Q.1. [[*MOD 7*]]: standard photolithography procedure
[equipment]: Eaton and GCA
[mask]: <PPII MASK>

Q.2. [[*MOD 10*]]: standard de-scum procedure
[equipment]: Technics plasma asher

Q.3. [[*MOD 11*]]: standard pre-implantation bake procedure

Q.4. P+ S/D IMPLANTATION
[equipment]: IONA
(a) Boron/10KeV/2.0×10^{15} *
(BF2 50 KeV)

Q.5. [[*MOD 6a*]]: Plasma Ashing Procedure

Q.6. [[*MOD 9*]]: standard oxide dip procedure(50 A)

Q.7. Oxide thickness measurement
250 A on p+ S/D

VIII. PASSIVATION, CONTACT OPENNING AND METALIZATION

R. PASSIVATION

{goal}: form 0.75 μm thick BPSG passivation layer

R.1. BPSG CVD: 0.15 μm undoped LTO, 0.6 μm boron phosphorous silicon glass deposited by a LPCVD process
[equipment]: TYLAN, bank 3, tube 12
[[*MOD 16*]]: standard TYLAN operation module
[program]:BPSG1
(a) load wafers at 400 C and evacuate the tube.
(b) stabilize temperature at 450 C
(c) undoped LTO deposition:
SiH4 - 90 sccm
O2 - 70 sccm
time - 30 min.
pressure- 320mtorr
thickness- 100-150 A,
(d) Boron-Phosphrous doped LTO deposition
SiH4 - 90 sccm
O2 - 70 sccm
PH3 - 10.3 sccm
B2H6 - 3.5 sccm
time - 30 min.
pressure- 330mtorr
final thickness- 8000 +- 3%
(e) flush and backfill the tube,
(f) unload the wafer at 450 C.

R.2. PSG reflow: reflow PSG for better metal step coverage
[equipment]: TYLAN, bank 1 , tube 3
[[*MOD 16*]]: standard TYLAN operation module
[program]:PSGDEN3
(a) load wafers at 750 C,
(b) densification at 959 C for 30 min. in N2 flowinmg at 1 slpm,
(c) unload at 750 C.

<<Note>>: immediate move to next step recommended

S. PHOTO-TRANSFER 7 <CONT MASK>

{goal}: transfer contact pattern and open contact holes

S.1. [[*MOD 8*]]: KODAK 820 photolithography procedure
[equipment]: Eaton and GCA
[mask]: <CONT MASK>

S.2. [[*MOD 10*]]: standard de-scum procedure
[equipment]: Technics plasma asher

S.3. [[*MOD 14*]]: standard post-bake procedure

S.4. contact etching: wet etch
[equipment]: wet bench 5 (in yellow room)
(a) DI H_2O, 15 sec.
(b) Buffered HF, 2 min.
(c) [[*MOD 1*]]: standard rinse-spin procedure
(d) [[*MOD 14*]]: standard post-bake procedure
(e) inspection: examine resist adhesion and oxide etch condition
(f) repeat (a) to (e) two more times
(g) DI H_2O, 15 sec.
(h) Buffered HF, 30 sec.
(i) [[*MOD 1*]]: standard rinse-spin procedure

S.5. [[*MOD 4*]]: standard resist stripping procedure

T. METALIZATION

{goal}: deposit 0.5 μm metal by sputtering

T.1. [[*MOD 9*]]: standard oxide dip procedure

T.2. Al/2%Si sputtering: 0.5 μm

U. PHOTO-TRANSFER 8 <METAL MASK>

{goal}: transfer metal pattern

U.1. [[*MOD 7*]]: standard photolithography procedure
[equipment]: Eaton and GCA

U.2. [[*MOD 10*]]: standard de-scum procedure
[equipment]: Technics plasma asher

U.3. [[*MOD 14*]]: standard post-bake procedure

U.4. Al etching
(a) DI H_2O, 15 sec.
(b) Al etchant (until pattern clear + 50% overetch)
(c) [[*MOD 1*]]: standard rinse-spin procedure

U.5. sintering
[equipment]: TYLAN, bank 1, tube 13 or 14
[[*MOD 16*]]: standard TYLAN operation module
[program]: N2H2ANEL
(a) load at 375 C (N2=1.0, N2/H2= 0)
(b) anneal, 20 min. (N2=1.0, N2/H2=1.0)
(c) pull at 450 C

STANDARD 100mm BERKELEY CMOS PROCESS MODULES

Version 1.0 (May 17, 1984)

[[MOD 1]] STANDARD RINSE-SPIN PROCEDURE (J. Lee)

[purpose]: to rinse to resistivity of 10 meg-ohm and spin dry

[equipment]: wet bench 1 and Fluorocarbon rinser/spinner (wet bench 1 is preferred because it is located near the spinner)

[summary]:

(a) Rinse in the first DI-H2O tank for 1 minute.
(b) Rinse in the second DI-H2O tank for 1 minute.
(c) Rinse in the final DI-H2O tank to 10 meg-ohm.
(d) Spin dry 2.5 min, 2400 RPM.

[detailed procedure]:

1. Press "RINSE-START" button light on.
2. Press "TANK-FILL" button lights on. Make sure that "TANK-DRAIN" button lights are off.
3. Wait until DI-H2O rinse tanks are filled.
4. Load wafers into a white teflon carrier .
5. Dip wafers into the first DI-H2O rinse tank (tank #1 or 4) for 1 minute. Make sure that DI-H2O overflows during rinsing.
6. Dip wafers into the second DI-H2O rinse tank (tank #2 or 5) for 1 minute.
7. Dip wafers into the final DI-H2O rinse tank (tank #3 or 6) until the resistivity meter reads at least 10 meg-ohm.
8. Load the carrier into the Fluorocarbon rinser/ spinner.
9. Make sure that the following setting is used:
   DRY TIME = 2.5 min
   SPIN SPEED= 2400 RPM
   "DRY ONLY" button light is on
10. Push "START" button to start the spin cycle. Check spin speed during spinning
11. When the "STOP" button light is lit, remove carrier from the spinner. Make sure that the shoulders of the carrier are up before removing.
12. To drain DI-H2O rinse tanks,
    a. press "TANK-FILL" button lights off,
    b. press "TANK DRAIN" button lights on,
    c. wait until DI-H2O rinse tanks are drained,
    d. press "RINSE START" off.

[[MOD 2]] STANDARD BARRACUDA CLEANING PROCEDURE (K-Y Toh)

[purpose]: to remove organic residue and complex heavy metals

[equipment]: wet bench 1, temperature controlled bath on the right; may need sulfuric acid and one packet of ammonium persulfate crystals.

<<Note>>: The bath should contain concentrated sulfuric acid. It should be a clear solution.

[summary]:

(a) Heat up the sulfuric acid in the temperature controlled bath to 120C.
(b) Add one packet of ammonium persulfate into the hot sulfuric acid bath if necessary. For the normal usage in the lab., a fresh mixture will last for about 4 to 5 hours.
(c) Wet wafers with spray gun if wafers are dry (do not use overflow tank for this purpose to avoid contaminating the tank).
(d) Immerse wafers in hot barracuda for 10 min.
(e) Rinse with DI water in the overflow tanks.

[detailed procedure]:

1. Turn on the temperature controller to the barracuda bath which is on the right side of wet bench 1. Check that the temperature setting is 120C. Temperature will be stablized in about 30 min. The bath contains concentrated sulfuric acid.
2. Put the wafers in the white teflon wafer cassette specially marked as "BRCD" with the vacuum wand.
3. Wait till the bath temperature has been stablized at 120 C, and just prior to immersing the wafers into the bath, add a packet of ammonium persulfate crystal into the bath if it has been idling for more than 5 hours. The crystals will mix with the hot sulfuric acid readily and oxygen bubbles will be released immediately if there are carbon residue in the bath.
4. Wet wafers with DI water using spray gun, if wafers is dry, to avoid bubbles sticking onto the wafer surface. (Do not use overflow tank for this purpose, so that you do not contaminate the tank.)
5. Immerse wafers and cassette in the hot barracuda bath for 10 min.
6. [[MOD 1]]: standard rinse-spin procedure
7. Turn off the temperature controller to the barracuda bath if you do not expect anyone to use it within the next hour.

[[MOD 3]] RCA CLEANING PROCEDURE

(currently not applicable)

[[MOD 4]] ACETONE RESIST STRIPPING PROCEDURE (K-Y Toh)

[purpose]: to remove soft photoresist on wafer

[equipment]: MTI/Omnichuck: execute "RUN,10" <CR>

Note: Program steps are in step 10 to step 16. Refer to Lab. Manual, Omnichuckman for program listing.

[summary]:

(a) Spin wafer at about 300 RPM.
(b) Dispense acetone for 10 sec.
(c) Rinse with DI water for 20 sec.
(d) Spun dry for 20 sec.
(e) [[MOD 2]] standard barracuda cleaning procedure.

[detailed procedure]:

1. Turn on power to the machine.
2. Terminal will response with "READY?".
3. Type: "RUN,10" on the terminal followed by <CR>. RUN button on the machine will flash.
4. Transfer your wafers to the blue wafer carrier in the machine and return it back to the loading platform.
5. Press the "RUN" button to start the program. Wafers will return to the wafer carrier after the process is completed.
6. Wait till the carrier retun to the original position before removing it from the platform.
7. Remove your wafers with vacuum wand and replace the wafer carrier to the loading platform.
8. Turn off power to the machine.
9. [[MOD 2]] standard barracuda cleaning procedure.

[[MOD 5]] NOPHENOL 922 PHOTORESIST STRIPPING PROCEDURE (K-Y Toh)

[purpose]: to remove hardened photoresist on wafer after hard-bake, low energy Boron implant or plasma etching processes.

[equipment]: wet bench 5; temperature controled bath on the left.

[summary]:

(a) Heat up nophenol 922 to 110 C.
(b) Immerse wafer in solution for 10 min.
(c) Rinse thoroughly in DI water.
(d) [[MOD 2]] standard barracuda cleaning procedure.

[detailed procedure]:

1. Turn on the temperature controller to the nophenol 922 bath, which is on the left of wet bench 1.
2. Check that the temperature setting is 110C. It will take about 30 min. to stablize at this temperature.
3. Transfer your wafers to the white teflon cassette specially marked as "922".

   <<IMPORTANT>>:

   Use only the cassette and cassette holder that are marked with "922". This is because the nophenol solution tends to stain the cassette and is difficult to remove.

4. Immerse cassette and wafers in the bath for

10 min. when the temperature is stablized.
(It is advisable to rotate your wafers by 90 degrees with respect to the cassette after about 7 min. to avoid incomplete dissolution of the photoresist hidden within the slots).

5. Remove the cassette from the bath. Inspect your wafers visually for resist residue. Repeat step 3 if necessary.
6. Rinse wafers 3 times with DI water in the overflow tanks number 1, 2 and 3, until the resistivity of the water is above 12 Mohm-cm.
   <<Note>>: water may become milky in the first rinse.
7. Turn off temperature controller if you do not expect anyone to use it within the next hour.
8. Transfer your wet wafers in a box, specially marked as "922 WET BOX" to the barracuda bath, wet bench 1. Please leave the "922" cassette and cassette holder in overflow tank 3.
9. [[MOD 2]] standard barracuda cleaning procedure.
   <<Note>>: Please return the box back to the nophenol sink, wet bench 5, after step 9.

[[MOD 6a]] PLASMA ASHING PROCEDURE (Y. Shacham)

[purpose]: to remove resist cross linked by high dose implantation process

[equipment]: Barrel Plasma Reactor 2

[special warning]:

(a) Explosion will occur if you ever attempt to pump on a chamber filled with O2!!
(b) Explosion will also occur if you attempt to activate O2 plasma at high O2 pressure.
<<Note>>: Read warning sign on the machine.

[summary]:

(a) Strip resist with O2 plasma: at 0.760 torr O2, 50W RF power, for 30 min.
(b) Inspect wafer for complete resist removal. repeat process if necessary.

[detailed procedure]:

1. Select reactor #2.
   turn on the power to the controller.
2. Turn off the VAC switch if it is on.
3. Turn on the VENT switch.
4. When the door pops open, remove the 2" wafer boat and shield. (Put it in safe and clean environment).
5. Put your wafers in the 4 " shield assembly, with photoresist surface at adjacent slots.
6. Put the shield assembly into the reactor chamber.
7. Close the reactor door.
8. Turn off the VENT switch.
9. Turn on the VAC switch.
10. Wait till the pressure monitor indicates

that the chamber pressure is below 0.100 torr. Then turn on O2 valve till the pressure rises to 0.760 torr.

11. Increase RF power slowly till O2 plasma is activated with the distinguished dark blue discharge. Reduce RF power to 50W.
12. Wait for 30 min. Reduce the RF power to 0. Turn off the RF power switch. Turn off O2.
13. Allow the chamber to cool down. turn off the VAC switch. Turn on the VENT switch and remove the shield assembly and replace the 2" wafer boat and shield assembly back to the original position. Ensure that the boat is positioned securely.
14. Turn off the VENT switch. Turn on the VAC switch.
15. Wait till the pressure drops to below 0.100 torr. then turn off the VAC switch and turn off the power switch to the controller.
16. Inspect the wafer under microscope for complete resist removal. Repeat process if necessary.

[[MOD 6b]] PLASMA ASHING PROCEDURE (K-Y Toh)

[purpose]: to remove photoresist using oxygen plasma
[equipment]: TECHNICS. parallel plate plasma etching system
[summary]:

(a) Photoresist ashing in O2 plasma;
etching rate is linear with time and power;
etch rate [A/min]=12.5*power [watts]

[detailed procedure]:

1. The following switches should be on : Auto, solenoid (vacuum), vent, power, gas 1.
2. Turn the power on, press the POWER button.
3. The system is being vented automatically.
4. Open the chamber till the cover is at a right angle to its closed state.
5. Put the wafers, face up, as close as possible to the center; be careful not to cover the vacuum inlet.
6. Set the time to the right time needed.
7. Press RUN, make sure the pressure is 180+-10 mtorr during the ashing .
8. At the end of the process the system is being vented automatically.
9. Repeat step 4.
10. Remove your wafers and pump down (manually) to 50 mtorrs before shut off.
11. Switch the valve off and shut the system power off.

[[MOD 7]] AZ 1450 PHOTOLITHOGRAPHY PROCEDURE
(currently not applicable)

[[MOD 8]] KODAK 820 PHOTOLITHOGRAPHY PROCEDURE (K-Y Toh)

8a: HMDS Treatment to Wafer Surface

[purpose]: to improve photoresist adhesion to the wafer
(needed only for wet etch process; skip this
for dry etch process)

[equipment]: wet bench 5

[summary]:

(a) Immerse wafers in HMDS vapor.
(b) Duration: 2 min.

[detailed procedure]:

1. Transfer your wafers to the blue wafer carrier in the HMDS container.
2. Check that there is HMDS in the container. You only need to have about 10cc of HMDS. Add HMDS into the container if necessary.
3. Place wafer carrier in the HMDS container and close the cover.
4. Wait for 2 min.
5. Remove the wafer carrier and replace the cover.
6. Transfer your wafers to the blue carrier from the Eaton machine.
7. Replace the original wafer carrier back to the HMDS container.
8. [MOD 8b] Kodak 820 photoresist coating immediately.

8b: Kodak 820 photoresist coating

[purpose]: to coat a 1.3um thick kodak 820 positive photoresist
layer on 4" wafer

[equipment]: EATON, program #10
Refer to Lab. Manual, Eatonman, for details
and program listing.

[summary]:

(a) Wafer must have been dehydrated with or without HMDS treatment.
(b) Execute program number 10.
  (i) dispense photoresist for 3 sec statically.
  (ii) spin at 4600RPM, at 10KRPM/s, for 25 sec.
  (iii) soft baked at 120C for 45 sec.
  (iv) cool on cold chuck for 45 sec. at about 23 C.

[detailed procedure]:

1. Turn on the sensor and purge supply gas valve to the machine. The gas valve is under the front panel.
2. Turn on the power to the machine. The machine will beep. Depress "TRACK 2" to stop beeping.
3. Depress "STOP" button. Select program #10. The temperature status indicator will indicate temperature low. It will take about 20 min. to reach 120C.
4. Check that the heat power switch is on, the cooling water flowmeter is in the 8 to 10 cm range.
   <<Note>>: You may transfer your wafers to the left

blue wafer carrier. For best coating result, it is advisable to include a dummy wafer for the first run , if the machine has not been used for a long time, i.e. put one dummy wafer at the very bottom of the wafer carrier. This is because the photoresist at the dispenser tip is likely to be contaminated.

5. When neither the high nor the low temperature indicator is on, the machine is ready for use.
6. Press "START" button to begin executing the program. Both loading and the receiving wafer carriers must be moved down when the program execution starts. If any of them do not moved at all, leave it up, replace it onto the platform, and depress the white reset button behind the plateform.
   <<Note>>: If the machine beeps at any point during the coating process, stop beeping by depress "TRACK 2" button and depress "ERROR 2 1" in sequence. The LED display window will display the error code. Refer to the quick reference guide in the drawer for error message.
7. When all wafers have been coated and loaded into the receiving wafer carrier, depress the white button on the box right behind the receiving platform to raise the carrier to the top position.
8. Remove your wafers and replace the carrier back to the receiving platform.
9. If you do not expect any one to use the machine within the next hour, turn off the power to the machine.
10. Turn off the sensor and purge supply gas valve under the front panel.

8c: Exposure

[purpose]: to expose 4" wafer coated with 1.3um thick Kodak 820 positive photoresist.

[equipment]: GCA DSW 6200, your own programs.
CMOS test chip programs are: CMOS WELL, CMOS ACTV, CMOS FPII, CMOS CAP, CMOS NNII, CMOS PPII, CMOS CONT, CMOS METL, CMOS PAD. Pass:1.
Step size are: 10.88571 in both x and y directions.
Refer to Lab. Manual, skwoo documents for details.

[summary]:

(a) Set automatic alignment switch and select dark alignment target.
(b) Exposure time: 0.3 sec, or otherwise stated.
(c) Focus setting: 250 or otherwise stated.

[detailed procedure]:

1. Log in to the GCA terminal.
2. Execute the appropriate program in SKT directory, e.g.
   "EXEC SKT CMOS WELL,1" <cr>

3. Set alignment switch to auto.
   Alignment target to dark target.
   Follow the interactive instructions on the terminal.
   <<Note>>: You may change the exposure and focus setting when prompted by the terminal.
4. The system will halt when the AWH (automatic wafer handler) is activated.
5. Place the appropriate mask in the stepper.
6. Transfer your wafers to the carrier at the loading platform near the front.
7. Press RESET button and SC button in front of the TV screen to start exposure.

   <<NOTE>>: For the WELL layer, there is nothing to align to. Depress RESET button, then SC and FIRST LAYER buttons simultaneously.

8. When all wafers are exposed, remove your wafers from the receiving carrier.
9. Log out from the terminal.

8d: Photoresist Development with Kodak 932

[purpose]: to develop 4" wafer with kodak 932 developer
concentration: 50%

[equipment]: MTI Omnichuck, execute "RUN" <CR>
Program is stored in step 1 to step 8.
Refer to Lab Manual, Omnichuckman, for details and program listing.

[summary]:

(a) Spin wafer at 6% down to 2% speed
(b) Dispense developer for 60 sec, at 5 psi tank pressure, 25C controlled temperature, using number 22 needle, which will dispense about 30 cc per minute.
(c) Rinse at 2% speed for 20 sec.
(d) Spun dry at 50% speed for 20 sec.

[detailed procedure]:

1. Turn on the power to the machine. The terminal will response with "READY?"
2. Activate the temperature controller by depressing the red button on the controller box inside the cabinet.
3. Transfer your wafers to the blue wafer carrier and return it to the loading platform.
4. Type "RUN" and <CR> at the terminal.
5. The RUN button on the machine will flash. Depress this button to begin executing the program.
6. When all wafers have been developed, wait till the carrier return to the up position before removing it from the platform.
7. Remove your wafers and return the carrier back to the loading platform.

8. Turn off the power to the machine.

8e: Inspection
[purpose]: inspect for clear development and correct line width
[equipment]: Microscope, Nanoline, or Vicker
[detailed procedures]:

1. Inspect wafer under microscope for clear development and correct line width. (refer to lab. manual for details)
2. If development is satisfactory, go to the next module in the process flow path.
3. If development is not satisfactory, proceed as follows:
   (i) [[MOD 4]] Acetone resist stripping procedure for all but double resist procedure. For double resist procedure, it is recommeded that you strip bath layers of resist with [[MOD 5]] Nophenol photoresist stripping procedure.
   (ii) [[MOD 13]] Standard dehydration procedure
   (iii)[[MOd 8]] Kodak 820 photolithography procedure; or repeat your double resist procedure.

[[MOD 9]] STANDARD OXIDE DIP PROCEDURE (S. Lester)

[purpose]: to remove 20 to 300A of oxide on wafer with no photoresist
[equipment]: wet bench 2
[summary]:

(a) DI water, 15 sec.
(b) Dip (H2O/HF=25/1, 25C, 1 min.)
<<Note>>: etch rate=200A/min., adjust dip time according to thickness of oxide to be stripped.
(c) Standard rinse-spin procedure

[detailed procedure]:

1. Clean HF temp. controlled bath (wet bench 2, left side)
   1.1 Rinse with DI water, aspirate.
   1.2 Repeat 1.1 ten times.
2. Fill dip tank with 3500 ml DI H2O, add 140 ml HF
   <<Note>>: This should be mixed ten minutes before use.
3. Press "temp control" button and be sure the temperature is set to 25C.
4. Press "Rinse start 1" button to fill rinse tanks. Be sure "tank fill" lights are on and "tank drain" lights are off.
5. Load wafers into a white teflon carrier and dip into DI water tank 3 for 15 seconds.
6. Dip wafers into HF bath--etch rate=200A/min. (3.33A/sec)
7. Standard rinse-spin procedure [[MOD 1]]

[[MOD 10]] STANDARD DE-SCUM PROCEDURE (K-Y Toh)

[purpose]: to remove residual resist film in normally clear areas
[equipment]: Barrel Plasma Reactor 2
[special warning]:

(a) Explosion will occur if you ever attempt to pump on a chamber filled with O2!!
(b) Explosion will also occur if attempt to activate O2 plasma at high O2 pressure. Read warning sign on the machine.

[summary]:

(a) Pre-heat reactor chamber to 65C with N2 plasma: at 1.000 torr N2, 60W RF power.
(b) De-scum with O2 plasma: at 0.760 torr O2, 50W RF power, for 2.5 min.

[detailed procedure]:

1. Select reactor #2. turn on the power to the controller.
2. Turn off the VAC switch if it is on.
3. Turn on the VENT switch.
4. When the door pops open, remove the 2" wafer boat and shield. (Put it in a safe and clean environment).
5. Put your wafers in the 4 " shield assembly, with photoresist surface at adjacent slots.
6. Put the shield assembly into the reactor chamber.
7. Close the reactor door.
8. Turn off the VENT switch.
9. Turn on the VAC switch.
10. Wait till the pressure monitor indicates that the chamber pressure is below 0.100 torr.
11. Turn on the nitrogen gas till the chamber pressure rises to 1.000 torr.
12. Turn on the RF power switch. Set the power meter to 300W range, and power level to HIGH.
13. Increase RF power slowly till N2 plasma in activated with the distinguished violet gas discharge. Reduce RF power to 60W.
14. Wait till chamber temperature rises to 70C. Then reduce the RF power to 0. Turn off the RF power switch. Turn off N2.
15. Wait till the chamber presure drops below 0.100 torr. Then turn on O2 till the pressure rises to 0.760 torr.
16. Increase RF power slowly till O2 plasma is activated with the distinguished dark violet discharge. Reduce RF power to 50W.
17. Wait for 2.5 min. Reduce the RF power to 0. Turn off the RF power switch. Turn off O2.
18. Allow the chamber to cool down. Turn off the VAC switch. turn on the VENT switch and remove the shield assembly and replace the 2" wafer boat and shield assembly back to the original position. <<Note>>: Ensure that the boat is positioned securely.
19. Turn off the VENT switch. Turn on the VAC

switch.
20. Wait till the pressure drops to below 0.100 torr. Then turn off the VAC switch and turn off the power switch to the controller.

[[MOD 11]] STANDARD PRE-IMPLANTATION BAKE PROCEDURE (B. Childers)

[purpose]: to bake out solvent in photoresist before ion implantation
[equipment]: Barrel Etcher
[summary]:

(a) Pressure: 400 mTorr
(b) N2 flow: adjust to attain 400mTorr
(c) RF power: 120 Watts
(d) Temperature: slow rise to 150 C
(e) Time: bake until temp. reaches 150 C

[detailed procedure]:

1. Check: Switch set to reactor 2, O2 off, N2 off, vacuum off, Main AC power on.
2. Open chamber vent.
3. Remove 2 inch wafer boat.
4. Load wafers in dedicated Tylan quartz boat. (Boat is in plastic box in VLSI region.)
5. Turn vent off, vacuum on. (Warning: do not pump with O2 on)
6. Pump down to about 100mTorr. (Should take about 5 minutes)
7. Open N2 flowmeter to achieve 400 mTorr
8. Switch on RF power. (Power control at zero, Range on 300)
9. Increase power slowly. (Watch for plasma ignition)
10. Set RF power at 120 Watts.
11. Check reflected power. (Should be <20 W and is usually 10-20 W)
12. Temperature should rise slowly to 150 C in 20 min.
13. Reduce RF power to zero when temperature reaches 150C.
14. Switch off RF power.
15. Cool down until temperature is 70 C or less.
16. Close N2 flowmeter.
17. Turn vacuum off, vent on.
18. Remove Tylan boat.
19. Replace 2 inch wafer boat.
20. Turn vent off, vacuum on (pump for 2 minutes)
21. Turn vacuum off, Main AC power off.
22. Return Tylan quartz boat to its storage location.

[[MOD 12]] STANDARD FURNACE CLEANING PROCEDURE (I-C Chen)

[purpose]: to remove heavy metals from the furnace tube
[equipment]: Tylan furnaces
[summary]:

1. TCA1:
   (a) Ramp up to 1000 C.
   (b) Pre-ox: 00:05:00 (02=4, N2=0)
   (c) TCA clean: 04:00:00 (TCA=on, O2=2.0)
       note: the TCA flow rate can not be specified in the recipe.
   (d) Post-ox: 00:05:00 (O2=4, TCA=off)

(e) Ramp down to 750 C.

2. TCACLEN1:
(a) Ramp up to 1000 C.
(b) Pre-ox: 00:05:00 (O2=4 N2=0)
(c) TCA clean: 00:05:00 (O2=4.0, N2CARR(TCA)=400)
01:40:00 (O2=1.0, N2CARR=100)
00:05:00 (O2=4.0, N2CARR=off)
(d) Ramp down to 750 C.

[detailed procedure]:
1. Put the floppy disc in the disc driver.
2. Type "LO TCACLEN1 tube#" for tube 5 and 6.
type "LO TCA1 tube#" for all the other tubes.
3. When the computer asks for cleaning time,
type "04:00:00".
4. If the loading is completed, a "good load" response
will appear on the screen.
5. Go to the tube and press "RUN" on the ROP (remote
operation panel).
6. After the cleaning is done, the alarm will activate.
press the "alarm ack" button on the ROP.

[[MOD 13]] STANDARD DEHYDRATION BAKE PROCEDURE (P-L Pai)

[purpose]: to dehydrate wafers before resist coating
[equipment]: TYLAN, bank 4, tube 15
[summary]:
(a) Temp= 600 C
(b) Time= 10 min.

[detailed procedure]:DEHID1
1. Inspect the wafers, the wafer must be clean after
[[MOD 2]] Standard Barracuda Cleaning Procedure.
2. Load the recipe EPROM to tube 15.
3. Press RUN in the Remote Operating Panel (ROP).
4. Wait 5 minutes after the tube is fully out.
5. Put the wafers in the boat with the vacuum tweezer.
6. Press ACK in the ROP, watch the wafers being loaded.
7. Wait approx. 15 minutes after the wafers are fully in,
this period includes load in, 10 minutes drying at
600 C in N2 and loading out.
8. Wait more 5 minutes after the wafers are out again.
9. Transfer the wafers back to the cassette.
10. Press ABORT in the ROP .
11. After the BEEP is heard press ACK on the ROP.
12. Leave when you see READY on the ROP display.
<<Note>>: The furnace should return to its idle state.

[[MOD 14]] STANDARD POST-BAKE PROCEDURE

(same as PRE-IMPLANTATION BAKE)

[[MOD 15]] STANDARD LAM ETCHER OPERATION PROCEDURE (P-L Pai)

[purposes]: to etch polysilicon and silicon nitride with plasma
[equipment]: Lam etcher
[summary]:
(a) Load the recipe.
(b) Load the wafers onto the boat.
(c) Run the recipe.
(d) Unload the wafers.
[detailed procedure]:
1. Insert the recipe module into the slot.
2. Load the recipe by pushing "save" button twice.
3. Enter recipe page by pushing "recipe" button.
4. Check process variables and enter etching time :
   (a) move the cursor to the proper position
   (b) enter via keyboard if numerical
   (c) enter via "field select" button if not numerical.
5. Load the wafers into standard 25 wafers cassette at the sending end.
6. Push "start" button.
7. When the process is finished, unload the wafers from the receiving end.

[[MOD 16]] STANDARD TYLAN OPERATION PROCEDURE (I-C Chen)
[purposes]: to load the recipe to the tube and start the operation
[equipment]: Tylan furnaces
[summary]:
(a) Load the recipe to the tube.
(b) Run the recipe.
(c) Load the wafers onto the boat.
(d) Push the wafers in.
[detailed procedure]:
1. Put the floppy disc in the disc driver.
   (the one located on the right hand side)
2. Load the recipe to the tube by typing
   "LO recipename tube#".
   e.g. load INITOX1 to tube 1, then type "LO INITOX1 1"
3. If the loading is completed, a "good load" response will appear on the screen.
4. Go to the tube and press "RUN" on the ROP (remote operation panel), and the puller will come out.
5. After the puller stops, load the wafers onto the boat.
6. Press the "ALARM ACK" button on the ROP, and the wafers will be pushed in.
7. After the puller fully stops, press "ALARM ACK" again.
8. (A few hours later) after the recipe finishes, the alarm will activate. press "ALARM ACK" to stop the alarm.
9. To get the wafers, press the "OUT" button on the ROP and the boat will be pulled out.
10. Wait a few minutes (to let the wafers cool down), then unload the wafers.
11. Press the "IN" button on the ROP to let the puller in.

Ion Implanter Correction for the 4 inch end station

$$F_x = \frac{X_w}{X_c} = \frac{129.4cm}{137.7cm}$$

$$F_y = \frac{Y_w}{Y_c} = \frac{147.9cm}{156.2cm}$$

$$F = F_x \times F_y$$

$$= 0.94 \times 0.95$$

$$= 0.88 \quad (12\% \text{ error})$$

$$Dose_{cup}(uC) = Dose_{wafer}\left(\frac{ions}{cm^2}\right) \times 4cm^2 \times 1.6\times10^{-13}\frac{uC}{ion} \times 0.88$$

$$= Dose_{wafer}\left(\frac{ions}{cm^2}\right) \times 0.56\times10^{-12}$$

X_w is the distance from the wafer to the x-scan coil

Y_w is the distance from the wafer to the y-scan coil

X_c is the distance from the faraday cups to the x-scan coil

Y_c is the distance from the faraday cups to the y-scan coil

100mm CMOS Mask Set Request

Name: ______________________________
Date: ______________________________
Office: ______________________________
Office Phone: ______________________________
Electronic Mail: ______________________________
Contract Number: ______________________________
Mask-Set Name: ______________________________

Non-Changeable Items -

Machine: GGA stepper
Place Feducials: Yes
Size of Plate: 5 inch
Type of Mask: Emulsion
Place Mask Names and Mask-Set Name on Plate: Yes

Masks (the ones to be made are marked with a '*' in the 'Make' column)

Make	Layer	Invert Mask
	WELL	No
	ACTV	No
	FPII	No
	CAP	No
	POLY	No
	NNII	No
	PPII	No
	CONT	Yes
	METL	No
	PAD	No

Remember to label your tape with your name, office and phone-number.

100mm CMOS Implant Request

Name: ____

Date: ____

Office: ____

Office Phone: ____

Electronic Mail: ____

Contract Number: ____

Number of Wafers: ____

Non-Changeable Items -

Machine: IONA Ion Implanter

Size of Wafer: 4 inch

Correction Factor: 0.56μCoulombs = 1×10^{12} ions/cm^2

The implant to be done is marked with a '*' in the 'Implant' column

Implant	Dose	Energy(keV)	Ion	Use
	2.0×10^{12}	150	Phos	N-Well
	1.0×10^{12}	100	Boron	Field
	2.3×10^{12}	30	Boron	Vt Adjustment
	1.3×10^{15}	100	Arsenic	Capacitor Bottom Plate
	3.0×10^{15}	100	Arsenic	N+ Source/Drain
	2.0×10^{15}	50	BF2	P+ Source/Drain

Take this form to Dick Chan (dick@merlin).

Designing with Berkeley 100mm CMOS [1]

Rick L Spickelmier (ricks@ucbcad)

May 25, 1984

1. Introduction

This document serves as an introduction to the use of the Berkeley 100mm CMOS process in the design of integrated circuits.

2. Facts About The Process

- N-well CMOS
- 9 mask process (10 with capacitors and bipolar transistors)
- 1.25μ Gate Length †[2]
- Symmetric N and P threshold voltages (0.8v and -0.8v) †
- 250Å gate oxide
- 30 Ω/□ polysilicon
- Capacitors and NPN bipolar transistors

3. Getting Started

In order to use the CAD tools mentioned in this report, you will need to get the following files and place the first two either in your home directory or in the directory where you plan to do your design.

merlin:~ee290NO/MASKS/lib/.KIC

merlin:~ee290NO/MASKS/lib/pat.cmos

merlin:~ee290NO/MASKS/lib/cmos-ucb.r

The *.KIC* file defines the layers, colors and stipple patterns used in the **kic** graphics editor. The *pat.cmos* file defines the layers and stipple patterns used by the **cifplot** plotting program. The *cmos-ucb.r* file defines the design rules used by the **lyra** design rule checker. This file

---

[1] This document is *designing.me*. It and its support files can be found in ~ee290NO/MASKS/doc on UCBMERLIN

[2] At the time of this writing, parts of the process have not been characterized; therefore all values marked by '†' are design goals rather than actual results.

should be placed in ~cad/lib/lyra/cmos-ucb.r and the **lyra** rule compiler, **rulec**, should be run (The file ~ee290NO/MASKS/doc/lyra-test.k is a test file for the cmos-ucb ruleset. See the **lyra** and **rulec** cadman pages for more information). If you do not have access to **UCBMERLIN**, the files are included in the first three appendices of this document. If you are not familiar with the CAD tools mentioned throughout this report, refer to section 9.

4. Layers Used In Design

Picked layers that are natural to design with (not the same as the actual mask layers).

The layout in **kic** is done in actual wafer dimensions (each **kic** lambda corresponds to 0.1μ on the wafer); the geometries are then resized to take into account lithography and processing biases. Therefore, any features below the minimum size specified in the design rules will disappear. The absolute minimum size for any feature is 0.2μ; this is the smallest size (when scaled by 10x) that the MANN 3600 pattern generator can flash (the grid of the pattern generator is 0.1μ).

Name	KIC Color/Pattern	Cifplot Pattern	Use
WELL	Orange/outline		N-well
CAP	Brown/stippled		Bottom Plates for Capacitors
POLY	Red/stippled		Gates and Interconnect
NNII	Light Green/stippled		S/D of N-devices, Substrate Contacts
PPII	Light Blue/stippled		S/D of P-devices, Well Contacts
CONT	Black/solid		Contacts
METL	Blue/stippled		Interconnect
PAD	Purple/outline		Probe/Bonding Pad Openings
SYMB	Yellow/outline		Labels/Symbolic Data
LYRR	Black/solid		DRC errors
LYRL	Black/solid		DRC error messages

Table 1. Layout Layers

Figure 1. CMOS Inverter, as laid out using **kic**

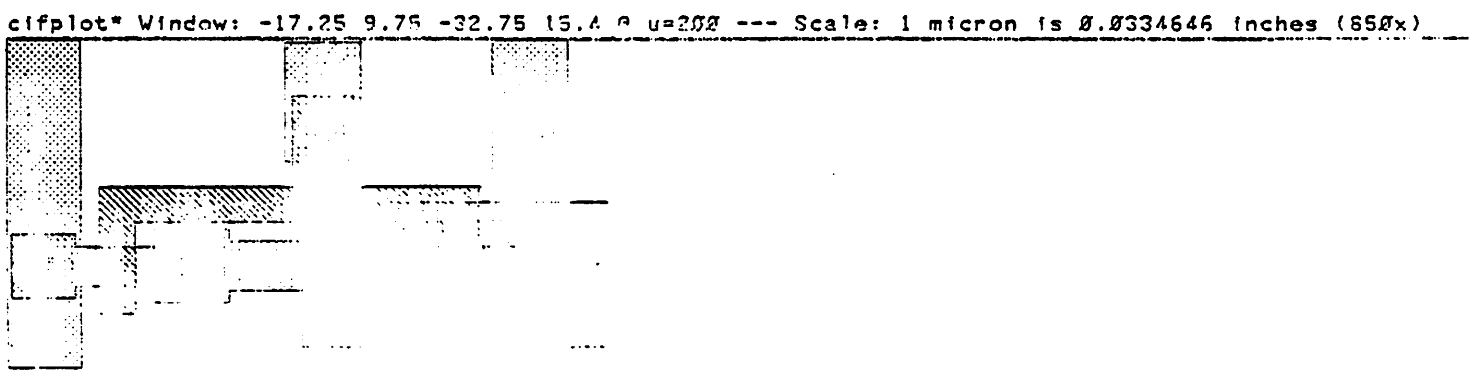


Figure 2. CMOS Inverter, after Growing/Shrinking

5. Design Rules [3]

Table 2 lists the design rules for the Berkeley 100mm CMOS process. The dimensions are in **kic** lambda (0.1μ). A more detailed and complete list can be found in[Wu83]

5.1. Design Rule Checking

Your design can be design rule checked from **kic** by using the *LYra* menu option. First you select the *TECh* menu option and type in *cmos-ucb*, then you select the *LYra* option to actually run the design rule checker. The *LYra* option will ask you to specify the area the you want to be checked. The rules check all of the design rules in table 2 and reports P-type transistors in the substrate and N-type transistors in the well.

6. Making a PG tape for the MANN 3600

Making the MANN 3600 PG tape from your **kic** files is a multistep process. The first step is to convert your **kic** files to cif. Then you must convert your cif file to a cif file with the actual mask layers grown/shrunk/inverted. Once this is done, you can write your PG tape.

Rule Name	Dimension	Description
Wa	23	width of active areas
Wg	13	width of poly (gate)
Wc	15	width of contact opening
Wm	35	width of metal
Saa	27	active spacing
Sgg	18	poly spacing
Smm	65	metal spacing
Swn+	26	spacing between well and n+
Swp+	26	spacing between well and p+
Sga	11	spacing between field-poly and active
Sgam	26	spacing between field-poly and active (metal)
Sacg	16	spacing between active and poly contact
Sgca	20	spacing between gate and contact
Ewn+	26	extension of well over n+
Ewp+	26	extension of well over p+
Ega	16	extension of gate over active
Eag	11	extension of active around gate
Eac	8	extension of active around contact
Esc	18	extension of poly around contact
Emc	12	extension of metal around contact
Wpad	600	width of pad
Empad	100	extension of metal around pad

Table 2. Design Rules

[3] Design rules and a program for generating new design rules based on lithography and process biases were developed by Albert Wu.

Name	Formation	Grow	Use
WELL	invert WELL	-2.2μ	N-well
ACTV	NNII union PPII	0.7μ	Active Area
FPII	invert WELL	-0.5μ	Field Region Threshold Adjustment
CAP	invert CAP	0.7μ	Capacitor Bottom Plates
POLY	POLY	0.25μ	Gates and Poly Interconnect
NNII	invert NNII	0.7μ	N-device Source/Drain, Substrate Contacts
PPII	invert PPII	0.7μ	P-device Source/Drain, Well Contacts
CONT	CONT	0.0μ	Contacts
METL	METL	1.5μ	Metal Interconnect
PAD	invert PAD	0.0μ	Probe/Bonding Pad Openings

Table 3. Mask Layers

6.1. Converting to actual mask layer cif files

To convert your design to the actual mask layers with the processing biases and inversions, you must run the following program (on **UCBCAD**):

~ricks/EE290N/make-mask-data *kic-hierarchy-root mask-data-file*

make-mask-data will create a file called *mask-data-file* containing mask data; it will also generate 15x cifplots of each mask layer. Your layout will be placed inside of a 1cm x 1cm frame with scribe lines, site-by-site and global alignment marks, and linewidth check patterns added. Running **make-mask-data** is the most time consuming part of the tape generation process. It can take up to 5 hours on a moderately loaded VAX 11/780 (load average of 3). Note that *mask-data-file* could be very large (Megabytes).

6.2. Generating the tape

The create a pg tape in a format that the MANN 3600 pattern generator can understand, you must run the following program (on **UCBCAD** or **UCBESVAX**):

~cad/bin/m36gen -c 0 0 -n *name mask-data-file*

To give you some idea of how long it will take to make the tape and the size of the tape you will need, here are some statistics gathered in the making of the EE290N/O testchip[Neu84] It took about 45 minutes on a moderately loaded VAX 11/780 to generate a tape of 250,000 flashes (boxes). Based on the amount of tape it took to write 250000 flashes, about 2 million flashes will fit on a 2400 foot tape.

7. Making the Masks

When you have made the PG tape, fill out a copy of the **100mm CMOS Mask Request** form (a copy is in the back of this report) and take it (along with the tape) to Kim Chan (kim@merlin, 409 Cory, x2-2716). To give you an idea of how long it will take to generate your masks, the MANN 3600 can shoot flashes on emulsion at a rate of up to 30,000 flashes per hour (however, 10,000 flashes an hour is a reasonable average).

8. SPICE Models

The following are SPICE models for the devices available on the process †

```
.model nmos (vt0 = 0.8 xj = 0.25μ)
.model pmos (vt0 = -0.8 xj = 0.25μ)
```

9. Other Information

More information on CAD tools used in this report can be found by typing the following commands:

```
cadman  kic
nroff  -me  ~cad/doc/kic.me
cadman  kictocif
cadman  ciftokic
cadman  m36gen
cadman  cifplot
cadman  lyra
cadman  rulec
nroff  -man  ~ee290NO/MASKS/doc/logical.1 (on UCBMERLIN only)
nroff  -man  ~ee290NO/MASKS/doc/mask.1 (on UCBMERLIN only)
cadman  ciftomann
cadman  cadrc
```

10. The Berkeley 100mm CMOS Team

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References

Wu83.

Albert Wu, "EE290N Design Rules," (esvax:~albert/cmos/ee290n/drg/document/ver1), EE290N Class Project (1983).

Neu84.

A.R. Neureuther, W.G. Oldham, and EE290N/O, "EE290N/O TestChip," ERL Memo 84/26, Electronics Research Laboratory, UC Berkeley (March 23, 1984).

Appendix A - Berkeley 100mm CMOS standard *KIC* file

```
Path? ( . /cad/lib/KicLibrary/fonts/bold  )

LayerName? WELL
RGB? 245 175 120
Filled? n
MinDimensions 0
Symbolic? n

LayerName? SYMB
RGB? 245 255 120
Filled? n
MinDimensions 0
Symbolic? y

LayerName? CAP
RGB? 100 0 0
Filled? 88 44 22 11 88 44 22 11
MinDimensions 0
Symbolic? n

LayerName? PPII
RGB? 90 255 255
Filled? 88 44 22 11 88 44 22 11
MinDimensions 0
Symbolic? n

LayerName? NNII
RGB? 0 245 0
Filled? 88 44 22 11 88 44 22 11
MinDimensions 0
Symbolic? n

LayerName? POLY
RGB? 255 0 0
Filled? 55 aa 55 aa 55 aa 55 aa
MinDimensions 0
Symbolic? n

LayerName? METL
RGB? 20 20 255
Filled? 55 0 55 0 55 0 55 0
MinDimensions 4
Symbolic? n

LayerName? CONT
RGB? 0 0 0
Filled? y
MinDimensions 0
Symbolic? n

LayerName? PAD
RGB? 155 0 255
Filled? n
MinDimensions 0
Symbolic? n

LayerName? LYRR
RGB? 0 0 0
Filled? y
MinDimensions 0
Symbolic? y

LayerName? LYRL
RGB? 0 0 0
Filled? y
MinDimensions 0
Symbolic? y

MenuText 11
MenuSelect 12
MenuHighlighting 6
FineGrid 7
CoarseGrid 2
GridSpacing 1
Highlighting 245 245 255
Background 160 170 170
ShowGrid
GridOnBottom
```

Appendix B - Berkeley 100mm CMOS standard *pat.cmos* **file**

"WELL",0x00000000,0x00000000,0x00000000,0x00000000,
0x00000000,0x00000000,0x00000000,0x10101010,
"NNII",0x04040404,0x11111111,0x04040404,0x00000000,
0x40404040,0x11111111,0x40404040,0x00000000,
"PPII",0x02020202,0x04040404,0x08080808,0x10101010,
0x20202020,0x40404040,0x80808080,0x01010101,
"POLY",0x08080808,0x04040404,0x02020202,0x01010101,
0x80808080,0x40404040,0x20202020,0x10101010,
"CONT",0x66666666,0x99999999,0x99999999,0x66666666,
0x66666666,0x99999999,0x99999999,0x66666666,
"METL",0x00000000,0x00000000,0x80808080,0x01010101,
0x00000000,0x00000000,0x10101010,0x08080808,
"SYMB",0x08080808,0x04040404,0x02020202,0x01010101,
0x80808080,0x40404040,0x20202020,0x10101010
"PAD",0x20202020,0x00000000,0x80808080,0x00000000,
0x00000000,0x00000000,0x00000000,0x00000000
"CAP",0xA0A0A0A0,0x10101010,0x80808080,0x50505050,
0x00000000,0x00000000,0x0F0F0F0F,0x00000000
"LYRR",0x08080808,0x04040404,0x02020202,0x01010101,
0x80808080,0x40404040,0x20202020,0x10101010
"LYRL",0x08080808,0x04040404,0x02020202,0x01010101,
0x80808080,0x40404040,0x20202020,0x10101010

Appendix C - Berkeley 100mm CMOS standard lyra rules file (*cmos-ucb.r*)

```
; n-well cmos rules (Berkeley 100mm CMOS: cmos-ucb)
; Rick L Spickelmier    5/16/84

; still needs CAP rules

(primary-layers
        (WELL (WE WELL))
        (CAP (CA CAP))
        (PPII (PP PPII))
        (NNII (NN NNII))
        (POLY (PO POLY))
        (METL (ME METL))
        (CONT (CO CONT))
        (PAD (PA PAD)))

(grown-layers
        (NNII-grow NNII 8)
        (PPII-grow PPII 8))

(composite-layers

        (bad-P-transistor (and POLY PPII (not WELL)))
        (bad-N-transistor (and POLY NNII WELL))

        (NNII-outside-WELL (and NNII (not WELL)))
        (PPII-outside-WELL (and PPII (not WELL)))

        (NNII-inside-WELL (and NNII WELL))
        (PPII-inside-WELL (and PPII WELL))

        (METL-over-POLY (and METL POLY))

        (METL-over-NNII (and METL NNII))
        (METL-over-PPII (and METL PPII))

        (POLY-over-NNII (and POLY NNII))
        (POLY-over-PPII (and POLY PPII))

        (CONT-over-NNII (and CONT NNII))
        (CONT-over-PPII (and CONT PPII))

        (CONT-over-POLY (and CONT POLY))
        (CONT-over-METL (and CONT METL))

        (POLY-gate-extension-NNII (and POLY (not NNII-grow)))
        (POLY-gate-extension-PPII (and POLY (not PPII-grow)))

        (NNII-gate-extension (and NNII (not POLY)))
```

```
        (PPII-gate-extension (and PPII (not POLY))))

(width METL 70 "Wm")
(ss METL 130 "Smm")

(width CONT 30 "Wc")

(width PAD 600 "Wpad")

(width POLY 26 "Wg")
(ss POLY 26 "Sgg")

(width NNII 46 "Wa")
(ss NNII 54 "Saa")

(width PPII 46 "Wa")
(ss PPII 54 "Saa")

(sep WELL NNII-outside-WELL 52 "Swn+")
(sep WELL PPII-outside-WELL 52 "Swp+")

(sep METL-over-POLY METL-over-NNII 52 "Sgam")
(sep METL-over-POLY METL-over-PPII 52 "Sgam")

(sep POLY NNII 22 "Sga")
(sep POLY PPII 22 "Sga")

(sep NNII CONT-over-POLY 32 "Sacg")
(sep PPII CONT-over-POLY 32 "Sacg")

(sep N-transistor CONT 40 "Sgca")
(sep P-transistor CONT 40 "Sgca")

(ext WELL NNII-inside-WELL 52 "Ewn+")
(ext WELL PPII-inside-WELL 52 "Ewp+")

; 24 = 32 - 8
(width POLY-gate-extension-NNII 24 "Ega")
(width POLY-gate-extension-PPII 24 "Ega")

(width NNII-gate-extension 22 "Eag")
(width PPII-gate-extension 22 "Eag")

(ext NNII CONT-over-NNII 16 "Eac")
(ext PPII CONT-over-PPII 16 "Eac")

(ext POLY CONT-over-POLY 36 "Esc")

(ext METL CONT-over-METL 24 "Emc")
```

```
(ext METL PAD 100 "Empad")

; bad transistor checks
(width bad-N-transistor 0 "BAD N T")
(width bad-P-transistor 0 "BAD P T")
```

NAME

logical — perform mask modifications

SYNOPSIS

Split < *cif-file*
Fix *LayerA LayerB*
Or *LayerA LayerB LayerC*
And *LayerA LayerB LayerC*
Invert *LayerA bounding-box LayerB*
AndNot *LayerA LayerB bounding-box LayerC*
Grow *LayerA amount LayerB*
Shrink *LayerA amount LayerB*
Box *LayerA LayerB*
Smash *LayerA scale LayerB*
Combine *LayerA LayerB ... LayerY* >*LayerZ*
Bb *+grow LayerA*

DESCRIPTION

Split breaks up a flattened cif file into individual files for each layer. Each layer file has the name of the cif layer.

Fix puts the data from the first file into the second file in a format that the logical operation programs can use.

Or, And performs the logical operation on the first two files and puts the result in the third.

Invert inverts the first file inside of the specified *bounding-box* and places it in the second file.

AndNot ands the first file with the inverse of the second file and places the result in the third file.

Grow, Shrink
grows/shrinks each side of the boxes in the first file by *amount* and puts the result in the second file.

Box put the data in the first file into the second file in a format that **Smash** can understand.

Smash puts the data in the first file (from **Box**) into the second file in cif format. *scale* is a scale factor applied to all coordinates.

Combine puts the individual cif layer files specified on the command line into a single file cif (adding cif layer commands as necessary). The output of this command can be sent directly to pattern generator tape making programs such as **m36gen(1)**. Thus, these programs bypass **ciftomann(1)**.

Bb calculates the bounding box of the data in the file and increases the size of the bounding box by an optional *grow*.

INFORMATION

Note that the input cif file must be flattened; this can be done by the following: ~cad/bin/flatten cif-file > flat-cif-file.

All programs allow the input and output file names to be the same. The format of the bounding box is "xl xb yr yt" (i.e. "0 0 1000 1000" - lower left, upper right)

These programs currently reside in ~ricks/EE290N/bin on UCBCAD and in order for them to work properly, ~ricks/EE290N/bin must be in your search path. Copies of these programs also exist in ~ee290NO/MASKS/bin on UCBMERLIN.

EXAMPLE

You have a cif file with 4 layers (AA, BB, CC, DD), 2 of them you want to OR into another layer (BB or CC -> EE), one (DD) is to be inverted and all of them are to be grown/shrunk.

```
flatten cif-file > flat-cif-file
Split < flat-cif-file
Fix AA AA
Fix BB BB
Fix CC CC
Fix DD DD
Or BB CC EE
Grow AA 10 AA
Grow BB 25 BB
Shrink CC 20 CC
Grow DD 15 DD
Grow EE 25 EE
Invert DD "'Bb +100 DD'" DD
Box AA AA
Box BB BB
Box CC CC
Box DD DD
Box EE EE
Smash AA 10 AA
Smash BB 10 BB
Smash CC 10 CC
Smash DD 10 DD
Smash EE 10 EE
Combine AA BB CC DD EE > pg-cif
m36gen -c 0 0 -n MASK-SET pg-cif
```

AUTHORS

Peter Moore
Rick Spickelmier

SEE ALSO

mask(1)
m36gen(1)
ciftomann(1)
Rick Spickelmier
Peter Moore

NAME

make-mask-data — convert EE290O format kic files into a pg file

SYNOPSIS

make-mask-data *kic-root pg-file*

DESCRIPTION

make-mask-data converts kic files laid out using the EE290O CMOS layout standards into a pg file that can be used to make masks for the EE290O CMOS process. Your layout will be converted to the physical mask layers, grown/shrunk to compensate for lithography and processing biases and placed in a 1cm by 1cm frame with aligment marks, linewidth patterns and scribe lines.

INFORMATION

This program can only be run on UCBCAD (~ricks/EE290N/bin/make-mask-data). A copy of the program exists in ~ee290NO/MASKS/bin/make-mask-data on UCBMERLIN.

AUTHOR

Rick L Spickelmier

NAME

ee290o — user interface for the files used in EE290O.

DESCRIPTION

ee290o allows a person to read and update the various files used in EE290O. It also has other features whose description is best left to the help file.

INFORMATION

ee290o currently resides on UCBMERLIN as ~ricks/ee290o. A copy also exists on UCBMERLIN in ~ee290NO/MASKS/bin/ee290o.

AUTHOR

Rick L Spickelmier

Test Procedure for 290 Wafer

by

Mike Chin

Joseph Pierret

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Berkeley, California

Test Procedure for 290 Wafer

This is a list of the equipment & steps in running the equipment required to test the 290 wafer.

1. Equipment

The equipment needed for the test consists of HPIB instrumentation controlled by software written in Pascal. It is anticipated that the instrumentation will remain in room 367, Cory Hall.

A. Instrumentation

1. HP 9836 Microcomputer with >= 1.4M RAM
2. HP 4145 Semiconductor Parameter Analyzer
3. Electroglass 2001x Automatic Wafer Probing System

B. Disk Software

1. BOOT
2. SYSVOL
3 ACCESS
4 CONTRL
5 DATOUT
6 ANLYZE
7 VT2

C. Documentation

1. The HP Pascal Language System User's Manual
2. The Pascal Handbook
3. Pascal Procedure Library User's Manual
4. General Purpose Test System for 290 Wafer Class Report for 290 5/84
5. A Fully Automated MOS Device Characterization System For Process Oriented Integrated Circuit Design Master's Report by Brian Messenger 1/84
6. Operations Manual for 4145

2. Steps

The following steps will allow the user to gather CSIM-SPICE parameters, Ids-Vds curves, contact chain & resistivity, Ids-Vgs curves, and meandor resistor information from the 290 wafer. All output data is on floppy disk **DATOUT:**. Plots of I-V curves can be obtained in between steps simply by pushing the **PLOT** button, followed by the **EXECUTE** on the HP4145.

1 Make sure power is off on 9836, 4145, & 2001x
2. Insert BOOT into righthand 9836 drive, SYSVOL into lefthand drive
3. Turn on power to 9836 & follow instructions on CRT to insert disks
4. Turn on power to 4145. IMPORTANT: check that fixture box is disconnected
5. Turn on power to 2001x
6. Turn on vacuum to 2001x
7. Place wafer on chuck

8. Follow instructions in Messenger or 290 Report to load & align wafer
9. Place probes over any die, site x=0,y=11 (upper left corner of die)
10 Stream CONTRL:startup (this sets up the coordinates for the 2001x)
11 Stream CONTRL:ivd2910ds.TEXT (this measures NMOS Ids-Vds curves for a W/L = 38.4um / 38.4um device)
12 Stream CONTRL:ivg2910ds.TEXT (this measures NMOS Ids-Vgs curves for a W/L = 38.4um / 38.4um device)
13 Stream CONTRL:sim2910ds.TEXT (this yields CSIM parameters for an NMOS device with W/L = 38.4um / 38.4um)
14 eXecute measure Answer the question with:
foo
CONTRL:mvleft.TEXT
5
end
15 Stream CONTRL:ivd2410cs.TEXT (this measures PMOS Ids-Vds curves for a W/L = 4.8um / 19.2um device)
16 Stream CONTRL:ivg2410cs.TEXT this measure PMOS Ids-Vgs curves for a W/L = 4.8um / 19.2um device)
17 Stream CONTRL:sim2410ds.TEXT (this yields CSIM parameters for a PMOS device with W/L = 4.8um / 19.2um)
18 eXecute measure Answer the question with:
foo
CONTRL:mvleft.TEXT
24
end
19 Stream CONTRL:cchains.TEXT (this measures a contact chain, the sheet resistance, and linewidth for PPII layer)
NOTE: the data stored in DATOUT:cchaino.TEXT must be looked at now, as it will be destroyed in the next step.
20 eXecute measure Answer the question with:
foo
CONTRL:mvdown.TEXT
2
end
21 Stream CONTRL:cchains.TEXT (this measures a contact chain, the sheet resistance, and linewidth for NNII layer)
NOTE: the data stored in DATOUT:cchaino.TEXT must be looked at now, as it will be destroyed in the next step.
22 eXecute measure Answer the question with:
foo
CONTRL:mvleft.TEXT
1
end
23 Stream CONTRL:cchains.TEXT (this measures a contact chain, the sheet resistance, and linewidth for POLY layer)
24 eXecute measure Answer the question with:
foo
CONTRL:mvup.TEXT
2
end

25 Stream CONTRL:meandors.TEXT (this measures a two meandor resistors)

26 Remove disks from 9836

27 Remove wafer from 2001x

28 Turn off power to 2001x,4145,9836

29 Turn off vacuum to 2001x

General Purpose Test System for 290 Wafer

by

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Table of Contents

General Purpose Test System for 290 Wafer

A general purpose wafer test system has been developed using the 9836 microcomputer, the 4145 test/measurement system, & the 2001x Electroglass wafer prober, and software to allow HPIB measurement of DC parameters. User-configurable control files allow for easy customization of test procedures, & the control file definition allows for the interfacing of additional HPIB instrumentation.

In addition to the device-independent measurement program, device-specific programs analyze single-device CSIM extraction, contact chains, alignment, Van der Paww, & yield.

1. Measurement Procedure

To gather data from a test structure, the user is expected to know what voltages & currents are to forced, ramped, & measured. Using either the text editor on the VAX or the 9836, a "controlfile" is created that a program on the 9836 will interpret and use to control all HPIB devices. A Pascal program, "measure", will then gather data as specified by the "controlfile", & write the data to an output "datafile".

The rest of this section will describe what buttons have to be pushed on the HP9836, HP4145, & Electroglas2001x to get the measurement program "measure" running, an example of how to produce standard NMOS IV curves, & the specification of the input controlfile.

1.1. Mini Guide to HP9836, HP4145, & Electroglas2001x and Example

The Pascal language/operating system is used because Pascal's data-typing and structures tend to lessen the effort of using, maintaining, & upgrading programs by various authors. Also, Pascal is compiled to 68000 object code, making it run ~ 5x faster than the BASIC on the 9836.

The operating system is menu-driven, which means that in the command mode, the user will generally push a single key to invoke a submode or utility program. There is no directory structure as in UNIX, but instead, the concept of a "volume". Keyboard, printer, & disks each have their own volume numbers. Additionally, volumes can be created in RAM, giving the appearance of very fast storage. Both commands & RAM volumes will be described in more detail later.

To get started, insert the disk labeled "BOOT" in the right hand drive, the disk labeled "SYSVOL" into the left hand drive, & turn on the power to the 9836. The computer will do some internal checking, extract software from both disks. Follow the directions, and upon completion of all instructions, the display at the top of the screen will say:

Command: Compiler Editor Filer Initialize Librarian Run eXecute Version ?

The 2001x must now be setup to allow initial die & site selection. The 2001x is quite complicated to use, & reading of the users manual is advised. For a quick cook-book approach, the next section, an appendix from B.S.M. thesis, is sufficient.

2001X PROBER SETUP INSTRUCTIONS (from B.S.M thesis)

A) Make sure that no foreign objects are on the prober stage, or on the wafer chuck.

B) If the probe card you want to use is not in the probe card rack, put the probe card you want to use in the rack and press it back into the edge connector. Make sure that all four screws which hold the probe card are tightened down securely.

C) Press the **ON** switch on the lower right front of the prober front panel.

D) Look at the Prober Video Display and answer the following questions as shown below. If you do not respond fast enough, a default response will be chosen by the prober, and it will move on to the next question. The prober display is in *italic* print, and the answer you should return is in **bold** print.

Type Message Plus Enter=> **Enter Key**
Wait for Pattern Rec I/O Test... **Wait about 30 seconds**
Rom Test? Y
Repeat Test? **Enter Key**

E) When the standard display comes up it should say ***XY MOTOR BLANK*** at the bottom of the screen. This means that the stage is floating on the platform and can be moved around. Pull the stage so that it is touching the front cushion on the prober platform. Now slide the stage along the front cushion to the right until it is contacting both the front and the right cushions. To hold the stage in place, hit the button inside the left side of the joystick control panel. (This button is recessed, and is in a cutout hole on the left vertical side of the joystick box)

F) On the front panel of the prober, above the label saying Model 2001X, is a small vacuum lever with a black handle. Pull the lever out so that it is perpendicular to the panel, and you should here a hissing noise as the vacuum turns on.

G) At this point, the I/O Mode should be set for the Prober. Turn to the control panel with the video monitor, and perform the **bold** actions to the *italic* video monitor requests

Press the blue 'Set Mode' key.
Select Line?= **7 and Enter**
IOMODE? 0=OFF, 1=SERIAL, 2=GPIB **2 and Enter**
If the line 9 GPIB (IEEE-488) address is not equal to 14, then set it to 14 as follows
Select Line?= **9 and Enter**
GPIB ADDRESS=? 1 TO 15 **14 and Enter**
Press **Enter** one final time to exit the "SET MODE" section.

Press the Yellow *ON LINE* Key on the monitor panel, which sets the prober up to receive signals from the 9836.

H) The stage up and down limits must now be either set or verified depending upon whether a new probe card will be used. Press the blue *SET PRMTR* key on the monitor panel, and observe the Z UP LIMIT and the Z DOWN LIMIT. The Z UP LIMIT should be about 30MILS above the Z DOWN LIMIT. Typical values might be Z UP LIMIT=370MILS and Z DOWN LIMIT=340MILS. If the probe card has not been changed, these values should have been previously setup, and require only verification. Using a new probe card requires that the LIMITS be lowered significantly, and then adjusted by raising the LIMITS incrementally until the probes barely touch the wafer when the chuck is up. This should be done by an experienced person. After the probes just touch the wafer, the Z UP LIMIT should be raised by 2.5 to 3.0 MILS to provide sufficient overdrive.

I) Place the wafer on the stage, and press both the *VAC* and the *LAMP* buttons on the joystick control panel. The video dislay should show that the wafer and chuck vacuum are on.

J) Press the *Align Scan* button on the panel with the joystick, and the stage should move under the probes. The index, jog and scan modes are selected by twisting the joystick. Faster movement is provided by pressing the red button on the joystick. The wafer is aligned by pressing the *Pause* key twice so that the stage is moving back and forth under the probes. The twist knob on the joystick control box is a theta adjust, and is used to align the wafer. Alignment is done by watching the wafer pass under a probe and using the theta adjust until patterns are tracking the probe across the wafer. Pressing *Pause* again will stop the movement.

K) Once the wafer is aligned, the wafer should be moved so that the probes are over the device to be tested, and then the stage is raised with the *Z* button. The stage may have to be lowered and moved so that the probes will contact the center of the pads.

(thank you, B.S.M)

Now turn on the HP4145 Parameter Analyzer. Simply press the "on" button in the lower left corner of the front panel. Make sure the operating system disk has been placed in the disk drive of the HP4145 first.

1.2. Plotter (OPTIONAL)

If a plotter is to be connected, follow these procedures:

There are 2 kinds of plotters which can be used:

1) Those with a 1-bit "listen only" DIP switch AND a 5-bit address DIP switch.

2) Those with a only a 5-bit address DIP switch.

If you connect type 1), simply connect up the HPIB cable and flip the "listen only" bit to "1". You can set the 5 address bits to any address, but you should probably just leave them as they are. If you connect type 2), set all 5 address bits to "1". (binary address = 31)

After a plot appears on the 4145 screen, hard copy output is obtained by pressing the "PLOT" button, followed by the "EXECUTE" button. After pressing just the PLOT button, plot limits will be displayed on the bottom of the 4145 screen. These represent Xminimum, Yminimum, Xmaximum, and Ymaximum values. The limits can be changed as desires, BEFORE pressing the "EXECUTE" button. They seem to vary with the type of plotter used. Limits of 100,100,10000,8000 will yield an 8.5 x 11 inch plot on the HP9872C, and 100,100,15000,11000 will yield the same size plot on the HP7470A plotter.

1.3. An Example - Standard IV NMOS Curves

We will now execute the program "measure". In this example, using 3 controlfiles, "measure" will move the prober to a specified location, control the HP4145 to measure the Ids-Vds curves of an NMOS device, and quit.

If automatic movement of the prober is to occur, the first thing which must be done *BEFORE ANY measureMENTS ARE TAKEN* is to set up the origin of the prober with respect to the die. This startup procedure has been automated for you. Follow these instructions:

1) Load a wafer and move the probes to position x=0,y=11 on the die of interest. See Appendix 1 for a map of the coordinates of the die, and Appendix 2 for an explanation of the 2X10 probe card and it's connections to the 4145.

2) Press "S". Answer the question "*Stream What File?*" with **CONTRL:startup.TEXT** .

   This will take only a few seconds and will set the origin of the die to the lower left corner. The probes will remain where you placed them, and this position will automatically be set to x=0,y=11. This position was chosen for initial probe placement since position x=0,y=0 does not have any probe pads on it. More on "Streaming" files later.

3) Now you are ready to measure.
   Press "X". This produces the prompt *Execute What File?* Answer with **measure.** This runs the program "measure".
   Answer the question with:
   Output File Name: **DATOUT:demout.TEXT**
   Input File Name: **CONTRL:mvright.TEXT**
   Number of Iterations: **29**

   The program will move the prober to the right 29 columns and place the chuck in the UP position. Then the "Input File Name:" prompt will return. Answer the question with:
   Input File Name: **CONTRL:mvdown.TEXT**
   Number of Iterations: **1**

   The program will move the prober down 1 row and place the chuck in the UP position. Again, the "Input File Name:" prompt will return. Answer with:
   Input File Name: **CONTRL:dnmosivds.TEXT**
   Number of Iterations: **1**

   The program will now measure the NMOS Ids-Vds curves of the device in column 29, row 10, with W/L = 38.4/38.4. When the prompt again returns, type in **end.** This will end the program "measure".

4) At this point, hardcopy output can be obtained, if desired, by pressing PLOT, followed by EXECUTE on the HP4145.

1.4. Control File Specification

In the above example, three controlfiles were used: mvright.TEXT, mvdown.TEXT, and dnmosivds.TEXT. The controlfile is text that tells "measure" what to send to the HPIB, when to expect data back, & what to do with the data. There are three sections that *must* be present in any controlfile. The first section is the comment section. This consists of text used to document what the file does. These lines are *not* sent out to the HPIB. This section may be of any number of lines, and is terminated by a line that contains somewhere in it the keyword "endcomment". The second section is the setup section. This contains lines that identify the address & mode (data gathering or not) of the HPIB device that will receive lines of text for setting of parameters. This section is terminated by a line that contains the keyword "endsetup". The last section is the measure section. It causes the 9836 to look for data at the latest HPIB address assignment, & to store the data according to the data gathering mode. This section is terminated by the keyword "endmeasure".

This cycle of three sections may be repeated any number of times. A controlfile is considered terminated when "measure" reads a line that contains both the keywords "endmeasure" and "stop". "measure" will then ask for another input controlfile name, & terminate itself by closing the outputfile if the keyword "end" is given instead of a valid controlfile name. HPIB assignments may be mixed up between cycles or within cycles, as long as there is no HPIB device-dependent conflict of setup & measurement.

In summary, the fundamental operation of "measure" is to look for various keywords in the controlfile ("endcomment", "endsetup", "endmeasure", "stop", "hpib=", "data back") which causes its mode of operation or the mode of the HPIB to change, but to simply send *everything else* in the control file to the HPIB. This means that "measure" is extremely flexible; just about any HPIB device can be accommodated, with no recompilation of the program. However, it assumes that the person devising the test is familiar with the HPIB commands needed to control the HPIB instrument(s), and also that the person devising the test understands what electrical quantities are to be forced

Three controlfiles, "mvright.TEXT", "mvdown.TEXT", and "dnmosivds.TEXT", were used in the example above. The first two move the prober to the right and down, and the last controlfile is for setting up the 4145 to measure the device.

Here is the contents of the controlfile "mvright.TEXT".

```
FILENAME: mvright.TEXT
endcomment
hpib=14
ZD
SP1X320Y800
SP2X0Y0
endsetup
MOX1Y0
endmeasure & stop
```

Here is the contents of the controlfile "mvdown.TEXT".

```
FILENAME: mvdown.TEXT
endcomment
hpib=14
ZD
SP1X320Y800
SP2X0Y0
endsetup
MOX0Y-1
endmeasure & stop
```

This is the contents of the controlfile "dnmosivds.TEXT" which actually measures one device on a site.

```
FILENAME: dnmosivds.TEXT
FOR SUBCHIP: Device
TEST SITES: fc4r2nmos thru fc7r2nmos
STRUCTURES TESTED: NMOS devices
ASSUMPTIONS:


PROBE CARD CONNECTIONS: (*) marks those used in this file
VS1*
VS2*
GND*
EXT*
VM1

EXPECTED RESULTS: this is the standard Ids vs. Vds transistor curve.
--------------------------------------------------------------
place the chuck in the ZU position (probes contacting wafer)
*************************endcomment*************************************
hpib=14
ZU
*************************endsetup*************************************
*************************endmeasure*************************************
measure the device with it's drain connected to SMU4
perform the measurement with the HP4145
*************************endcomment*************************************
hpib=17  and get data back
IT2 CA1 DR0 BC
DE CH1
CH2
CH3
CH4,'VDRN4','IDRN4',1,1
VS1,'VGATE',2
VS2,'VBODY',3
VM1
VM2
SS VR1,0,5,.1,10E-3;VP 0,1,6,10E-6;SC2,0
SM DM1, XN'VDRN4',1,0,5;YA'IDRN4',1,0,1E-3
MD ME1
*************************endsetup*************************************
DO 'IDRN4'
*************************endmeasure & stop*******************************
```

The first two control files are quite similar. Each of them controls prober movement. The comment section of each of the first 2 files describes the general purpose of each control file. Any text in the comment section will not appear on the HPIB.

The first setup section line should always contain "hpib=xx", where xx is the address of the device, and should also contain the key words "data back" if the device will send back valuable data, such as the HP4145 does. This first line in each of the first two files tells "measure" that the current HPIB address for the next set of HPIB commands will be at 14, and that the data coming back from address 14 should not be stored in the output datafile because it did *not* find the keyword "data back" in the same line. The rest of the lines in the setup section for the 2001x are HPIB commands sent out (at address 14) to the HPIB. These are the raw HPIB commands that the 2001x expects to see, and can be obtained from the 2001x I/O manual.

The measure section for the 2001x contains a single line that causes "measure" to move the probes one position immediately to the right in the first file, or down in the second file. The "Number of Iterations" question answered in the program "measure" causes multiple movement. This line also causes the program to look for characters coming back from the currently active HPIB device. The sending of these characters is specified in the 2001x I/O manual, & is simply an indication of health of the device. In general, these status characters will be device specific, & may or may not be written to the output datafile, at the discretion of the person setting up the test. If you want these characters in your datafile, include the words "data back" on the same line as "hpib=xx" in the setup section. "measure" will stop after doing this measurement, and displays the prompt "Input File Name". The only reason that "measure" does this is that the keyword "stop" is present in the last line with "endmeasure".

The next control file is another cycle of comment, setup, & measure for the 4145. A difference between this file and the first two is that on the first line of setup, the keyword "data back" is present, so when the 4145 sends back its data in response to the "DO 'IDRAIN'" line, the 9836 will store this data into a user-specified output datafile, which for this demonstration, is "DEMOUT.TEXT".

Although for sake of clarity, the two instruments were setup and measured in three distinct cycles, it is possible to mix up different HPIB setup & measurement commands within a single cycle, as long as the user takes care to precede a group of HPIB commands with the appropriate "hpib= xx" command. To create a cycle for those devices which do not send anything back over the HPIB (listen-only), a line containing "endmeasure" must follow the "endsetup" line.

1.5. Stream Files: Automatic Execution at the Touch of a Finger

The above section detailed the procedure to obtain NMOS Ids-Vds curves. A utility, called "Streaming", has been provided in the HP9836 Pascal Operating System. Streaming allows you to enter all of the keystrokes that you would normally type in from the keyboard, into a text file. This text file can then be "streamed" and the 9836 will look in this file for the keyboard entries. This greatly reduces the amount of typing you need to do if you want to perform the same task over and over again. We have already seen an example of Streaming when after we powered everything on and Streamed the file "CONTRL:startup.TEXT". This file was simply a substitution for typing in a bunch of lines from the keyboard. All the things we would have typed in were contained in the file "CONTRL:startup.TEXT". This file was then "Streamed" to the 9836.

As a second example, the task performed above will now be executed again from a stream file.
Press "S". Answer the question *Stream What File?* with **CONTRL:NMOSDEMO**. The contents of CONTRL:NMOSDEMO.TEXT are:

```
xmeasure
demout.TEXT
CONTRL:mvright.TEXT
24
CONTRL:mvdown.TEXT
1
CONTRL:dnmosivds.TEXT
1
end
```

Notice that these are the same keystrokes that were entered by you from the keyboard above. They have simply been placed in a file CONTRL:NMOSDEMO.TEXT and "streamed" to the 9836.

2. Detail of Wafer Measurement & Analysis

One goal of the wafer test system was to make the measurement software device-independent. This ensures that the user gains familiarity with the equipment available to test the device, as well as familiarity with the method of testing the device. Another goal was to separate the measurement (device-independent) of the data from its analysis (device-dependent). This goal has the beneficial result that this encourages the extensive use of files as intermediate data input & output, allowing the usage of actual or simulated data, & making accessible what would otherwise be hidden inside executing code (sort of like pipes & tees on UNIX).

2.1. Single-Device CSIM Extraction

"measure" uses a control file for that will sweep the gate, body, & drain voltages and write out the drain current values to a user-specified file. A reduction program called "CMEAS" will then reduce the large amount of data from "measure", keeping only the largest drain current values. The output datafile from "CMEAS" is then used as input to "SSIM" which produces the 17 CSIM parameters, & writes them to a user-specified output file.

2.1.1. CSIM Measurement

The control file for the extraction of csim parameters requires that the gate sweep step depends on the maximum Vdd and be related in the following fashion:

Vddmax	Gate Sweep Step
<= 3	.05
<= 5	.1
<= 10	.2
> 10	.5

The gate will be swept from 0 to Vddmax, while the source-body voltage is swept from Vddmax to 0 in 6 equal steps. These swept voltages will be applied for four different drain values: .1, .2, Vddmax-.5, and Vddmax volts. Because the 4145 can only sweep two sources at once, a control file containing four cycles for each of the drain voltages is used. Assuming a Vddmax of 5 volts, this results in 4 (drain voltages) x 51 (gate voltages) x 6 (body biases) for a total of 1224 measurements per device.

2.1.2. CSIM Analysis

The analysis of the raw data file is performed in two separate programs. The first program is "CMEAS". It will prompt for temperature (degrees Celsius), tox (in angstroms), device width & length (in microns), Vddmax (in volt), type of device (NMOS or PMOS), and threshold type (enhancement, zero, or depletion). It will then ask for input and output datafiles, and then reduce the 1224 measurements to 4 (drain voltages) x 6 (body biases) x 5 (gate voltages). These 120 values plus the gate, drain, & body sweeps, & all the information entered from the prompts are written to the output file. The format of the output file is:

1	device_width
2	device_length
3	temperatureK
4	device_tox
5	vdd
6	enhancement_depletion
7	device_type
8	vbody biases
9	vdrain biases
10	idrain measured values
11	vgate biases

This segment of code originated from B.S.M original code, but was extensively modified to make it independent of device pinout. Note that some of the information requested in "CMEAS" must have already been known in order to properly set up the controlfile for "measure".

The second program required for CSIM analysis is "SSIM". It will prompt for the input & output datafiles names. It is almost untouched B.S.M code, with additions to read parameters from the input file, and write them out to the output file. The order of variables written to the output file is:

1	U0
2	X2U0
3	VFB
4	PHIF2 (always .6 volts)
5	K1
6	K2
7	U1
8	X2U1
9	X3U1
10	ETA
11	X2ETA
12	X3ETA
13	BETA0
14	X2BETA0
15	BETA0SAT
16	X2BETA0SAT
17	X3BETA0SAT

It should be noted that both the original B.S.M "CSIM" code and the new "SSIM" code are not fool proof. Given what seems to be perfectly valid data from a discrete NMOS device with large body effect (3N4251), both programs wère unable to produce single-device CSIM parameters, but instead ran into "divide by zero" errors. This is probably due to numerical analysis problems common to both "CSIM" and its near-identical hack-out "SSIM".

2.2. NMOS & PMOS Transistor IVds Curves

This describes the electrical quantities that need to be applied to the 2x5 pattern to measure Ids versus Vds for both PMOS & NMOS transistors.

Kic Filenames of test sites: fc0r2pmos thru fc3r2pmos & fc4r2nmos thru fc7r2nmos
Subchip: Device (Device Drop-in has a different pad configuration)
Description:
Pad 3 (source) is grounded.
Pad 2 (body) is grounded.
Pad 11 or 12 or 13 or 14 (drain) is ramped from 0 to 5V (NMOS) or from 0 to -5V (PMOS) both in 0.1V increments.
Pad 1 (gate) is ramped from 0 to 5 V (NMOS) or from 0 to -5V (PMOS) both in 1V increments.
Pad 4 (external) MUST be disconnected when measuring NMOS, and can float or be connected to -5V when measuring PMOS.

2.3. NMOS & PMOS Transistor IVgs Curves

This describes the electrical quantities that need to be applied to the 2x5 pattern to measure Id versus Vgs for both PMOS & NMOS transistors.

Kic Filenames of test sites: fc0r2pmos thru fc3r2pmos & fc4r2nmos thru fc7r2nmos
Subchip: Device (Device Drop-in has a different pad configuration)
Description:
Pad 3 (source) is grounded.
Pad 2 (body) is ramped from -5 to 0V (NMOS) or from 5 to 0 (PMOS) both in 1V increments.
Pad 11 or 12 or 13 or 14 (drain) is held constant at 0.1V.
Pad 1 (gate) is ramped from 0 to 5 V (NMOS) or from 0 to -5V (PMOS) both in 1V increments.
Pad 4 (external) MUST be disconnected when measuring NMOS, and can float or be connected to -5V when measuring PMOS.

Control files exists that will measure all 4 devices at each 2X5 Pad location or measure just 1 device at a single location. The single device measurement allows hardcopy output to be obtained from the HP4145 to the plotter.

2.4. Contact Chains (contact yield)

This describes the electrical quantities that need to be applied to the 2x5 pattern to determine continuity through active area & poly contact chains. These tests give go/nogo information for metalization and its yield.

Kic Filenames of test sites: ac1r1NACTV, ac0r1POLY, ac1r2PACTV
Subchip: Process Drop-In
Description:
Pad 2 is grounded.
Pad 11 has a current forced through it.
The voltage is measured at Pad 11.

It should be less than the compliance value, but non-zero. This measurement is immediately followed by measuring a Cross Bridge structure, which is located at each of these same locations. See the next section.

2.5. Cross Bridge (Van der Pauw & linewidth)

This describes the electrical quantities that need to be applied to the 2x5 pattern to determine sheet resistance & actual linewidth of active areas & poly.

Kic Filenames of test sites: ac1r1NACTV, ac0r1POLY, ac1r2PACTV
Subchip: Process Drop-In
Description:
Pad 2 is grounded.
Pad 14 has a current forced through it.
Pads 5 and 15 sense the voltage for typical Van der Pauw measurement.
The Sheet resistance of the structure is determined.
Then Pads 12 and 13 sense a voltage drop
Using the calculated Sheet Resistance, the linewidth can be determined.

3. Hints to using the 9836

Since the previous list of control & analysis file will characterize only some of the structures on the 290 wafer, it is possible that someone will be able to devise a test for some of the structures that were deemed untestable. Also, it may turn out that modifications of existing control files, or creation of new analysis programs may be desired in the future. All of these will require using the 9836 Pascal Operating system to create new text files and possibly executable code.

The user will need three manuals in order to create new Pascal Programs:

The HP Pascal Language System User's Manual The Pascal Handbook Pascal Procedure Library User's Manual

The first manual documents the operating system and its utilities such as the editor, compiler, & filer. It is the first manual that should be read. Once the user needs to create Pascal programs, the Pascal Handbook should be read as it documents the differences between the HP & many other Pascal dialects. The Procedure Manual should be read once HPIB control is needed. It documents the software modules that need to be imported for HPIB control from Pascal. These manuals should be kept in the storage drawer of the 9836 table. Copies of these manuals are also available for short loan from the BIAS group in 325 Cory.

Each of these manuals is quite large, & most questions can be answered from them, but it usually requires extensive excavation. Unfortunately, the Language System User's Manual contains errors or omissions to the version of software used to create "CSIM" and this test system. Most of the errors concern illustrative examples for the editor and filer that are incorrect in minor details, & do not affect the actual usage of the utility programs. For example, on powerup, the system looks for "AUTOSTART", not "AUTOSTART.TEXT", and the Filer uses "Translate", not "Transfer". However, there is a major omission of the "What" command in the operating system level that will be described in a later section.

The next few sections will describe some idiosyncrasies of the 9836 that were discovered. They will shorten the learning curve of someone needing to create Pascal programs. However, they will not take the place of reading the manuals.

After booting up, the user is confronted with the command mode. The top line of the screen will display various choices of submodes which can be invoked by typing in the letter that is capitalized. On a just-booted system, none of these submodes are actually available unless they happened to be on one of the disks inserted on power up.

3.1. Permanent

Although all utility programs can be used off of disk, it is much faster to load them Permanently into memory (this also saves wear & tear on the disks, which have a finite number of accesses to them). A normal software working environment would have at least three utility programs:

Filer (which you need even to list a disk contents)
Editor (to create new controlfiles & Pascal programs)
Compiler (to transform the files into executable code)

The next section is adapted from B.S.M thesis. It describes in detail how to get these 3 programs loaded assuming that there is no "AUTOSTART" file on "SYSVOL". The software for 290 testing does contain an "AUTOSTART" file that facilitates booting, & it will be described later.

9836 SETUP INSTRUCTIONS (from B.S.M thesis)

A) Insert *Pascal 2.0 Boot Disc* in the right (#3:) Disc Drive. Insert *Pascal 2.0 Sysvol Disc* in the left (#4) Disc Drive. Turn on the 9836 with the switch on the front bottom right of the machine by pressing the switch in.

B) The operating system will now be loaded from the Boot Disc. Enter the date and time when they are requested, or hit *Enter* to skip these inputs.

C) Insert the *Pascal 2.0 Access Disc* in the right (#3:) Disc Drive. The following instructions will load the filer and the editor from the Access Disc into main memory. Enter the Bold values in the following sequence.

P {this selects the permanent load operating system option}
Load what code file? **#3:EDITOR.**
P
Load what code file? **#3:FILER.**

D) Insert the *Pascal 2.0 Compasm Disc* in the right (#3:) Disc Drive. The following instructions will load the filer and the editor from the Compasm Disc into main memory. Enter the Bold values in the following sequence.

P {this selects the permanent load operating system option}
Load what code file? **#3:COMPILER.**

(thank you, B.S.M)

Additionally, the user will probably want to load the VAX communication package, "VT2". This program allows file transfer between UNIX & the 9836, useful for file backup, & raw data transfer (in case someone prefers to do all analysis in C, for instance). The following section is adapted from B.S.M. thesis, with modifications to the baud rate (from 9600 to 1200) & handshake configuration (from non-modem to modem, accompanied by flipping dipswitches in the serial I/F to match the BIAS group's I/F) as recommended by Frank Ma of the BIAS group to achieve more reliable communication.

9836 TO VAX LINK (adapted from B.S.M. thesis)

A) To transfer files to the Vax, the RS232 Data Communication Board must be in the back of the 9836, and it must be connected to a port selector or a modem. Insert the *Pascal 2.0 VTCODE Disc* in the right Disc Drive.

P {this selects the permanent load operating system option}
Load what code file? **#3:NEWKBD** {*This is a new keyboard file needed by VT2*}
X {*This selects the execute option*}
Execute what file? **#3:VT2**

B) When the program is loaded, a menu will appear, and the user must load in the configuration as follows.

Main> **4** {option to create a configuration}
Selection? **1** {VAX/UNIX}
Rate? **1200** {baud rate}
Selection? 3 {Modem connection}
Main> 1 {go to emulator mode}

C) Press the port selector switch, and log into a VAX account as using normal procedures. The terminal type is 2648. To perform file transfer, press *CTRL and EXECUTE* at the same time. This returns the program to an execution menu.

Execute> 3 {file transfer to host}
Enter host file name: **Your VAX FILE NAME**
Enter local file name: **A name like #45:csimout.TEXT**

Multiple files can be transferred, or the 9836 can be used as a Vax terminal. To Exit the program, select the terminate emulator option.

(thank you, B.S.M)

Each of these 4 programs is now resident in the 9836, ready for immediate execution. With a little bit of practice, they can be loaded in about 2-3 minutes.

3.2. Memvols

Once again, the 9836 doesn't use directories; it uses "volumes". Here is a list of the default volume assignments.

1	keyboard/CRT
3	Right Disk Drive
4	Left Disk Drive
6	Thermal Printer

Some interesting options occur with the use of volumes. For instance, when the "measure" program prompts for input file name, if it receives "#1:", the user can then type in the controlfile from the keyboard line by line. If the user specifies "#6:" as the output file, the output data will go to the printer.

The most useful option of a volume is to create a "memory volume" (memvol). This allows more rapid program development, since editing & compiling take place without disk accesses, & more rapid execution of programs that use files for intermediate storage occurs.

The following section was taken from B.S.M's thesis to demonstrate the creation of memory volume. Reading of the Language Manual is recommended for further insight.

CREATING A MEMVOL (from B.S.M. thesis)

M {creating a Memory Volume}
****CREATING A MEMORY VOLUME****
What unit number? **#45:** *How many 512 byte blocks?* **1000**
How many entries in directory? **0**
#45: (RAM:) zeroed

(thank you, B.S.M.)

3.3. What

This seems to be an undocumented command. It can be displayed by toggling the command menu by typing "?", but there is no description of it in the Language Manual, nor is it discussed in B.S.M.'s thesis although it seems that he did use it for "CSIM" development.

Its main use is to declare memory volumes to be default, sysvol, & library volumes. With a memvol to be default, it is not necessary to prefix all filenames with "RAM:" to use a current working image of a disk in RAM for extremely fast editing & compiling sessions. Using the same memvol as sysvol allows streamfiles to be co-resident, greatly speeding up automated command processing. Declaring RAM as library access allows the loading of the HPIB library code "LIBRARY", which increases compilation speed for code that imports HPIB modules, once "LIBRARY" from the SYSVOL disc has been filecopied into the memvol.

Assuming that a memvol has already been established, here is a sequence of command that will install default, sysvol, & library volumes into RAM. Unfortunately, because this is a screen oriented session, it is difficult to describe what happens. The user should try this on the 9836 rather that fathom it all out here.

THE "WHAT" COMMAND

Enter the Bold values in the following sequence.

W {this selects the What operating system option}
D {this sets up to change the default volume}
RAM: {this selects the current memvol to be the default volume}
S {this sets up to change the system volume}
RAM: {this selects the current memvol to be the sysvol}
B {this sets up to change the library volume}
RAM:LIBRARY. {this selects the current memvol to be the library volume}
Q {this returns to the main command mode }

3.4. Compiler

The compiler, especially when Permanent loaded, is quite fast. However, its error diagnostics are abysmal. The compiler simply prints out a one or two word message accompanied by the number (1-999) that the user must look up in the compiler manual for more detailed information. If a syntactical error is made in the source, it can usually be spotted without having to read the manual. However, there are a number of errors that are related to compiler directives and compiler environment that are quite confusing, & reading the manual is not at all enlightening

3.4.1. Compiler Directives

One directive that should be set for large programs is "$REFS". This specifies the size of the temporary external reference file which is copied onto the default volume. B.S.M. uses "$REFS=150" for "CSIM". Since the units are volume records, and a typical memvol is 1000 records, this seems to be a good size to use.

Another directive that was used for "measure" was "$SWITCH_STRPOS$". This enables the use of the string function "strpos", which uses an ordering of parameters exactly opposite that of the string function "pos". This was done to eliminate the confusion that arises when some variable is called "pos". See the Pascal Handbook for a full discussion.

Finally, both B.S.M and the 290 wafer test software turn on the "$UCSD$" directive. This is a misleading directive since not all UCSD compatibility is achieved by doing this. A listing of the differences is in the compiler section of the Language Manual.

3.4.2. Error 900s

These errors mean that there is something wrong with the compiling environment. Some of them are straightforward to fix; if it needs more reference space, then the "$REF=$" should be increased. On the other hand, insufficient room errors are not so obvious. An error saying that there is not enough space on the working volume can usually be fixed by "Krunching", with the filer (see the filer section of the Language Manual), the volume to retrieve all free records.

3.5. Streamfiles

A streamfile is an ordinary text file whose contents is used instead of keyboard input to the operating system command. Reading the contents of a streamfile will not always reveal what is going on, since it is only the "I" part of "I/O".

3.5.1. Boot Up Streamfiles

Here are the contents of various streamfiles that Permanent load the Editor & Filer, & the 290 test software. These are the files which are "Streamed" upon following the instructions at Boot Up time.

AUTOSTART
=A 290 Wafer Test [Press Enter]
8MAY
0
M#45
1000
0
$SYSVOL:AUTO1

AUTOSTART entered in a bogus date & time, created a memory volume, & then streamed another file, AUTO1.TEXT

AUTO1.TEXT
=A Replace BOOT with ACCESS [Press Enter]
pACCESS:EDITOR.
pACCESS:FILER.
FFSYSVOL:LIBRARY
RAM:LIBRARY
Q
WBRAM:LIBRARY.
SRAM:
DRAM:
Q
SSYSVOL:AUTO2

AUTO1.TEXT Permanent loaded the Editor & Filer, assigned sysvol, default & library to the memvol, & streamed another fileer file, AUTO2.TEXT.

AUTO2.TEXT
=C Replace ACCESS With VT2 [Press Enter]
pVT2:NEWKBD
pVT2:VT2
SSYSVOL:AUTO3

AUTO2.TEXT Ploaded (Permanent loaded) the VAX communication package, & then streamed another file, AUTO3.TEXT..

AUTO3.TEXT
=A Replace VT2 With CONTRL [Press Enter]
FFCONTRL:=
S
Q
SSYSVOL:LASTAUTO

AUTO3.TEXT copied the entire contents of the disk CONTRL into the current default volume (RAM), & then streamed another file, LASTAUTO.TEXT.

LASTAUTO.TEXT
=Z Replace SYSVOL with DATOUT [Press Return]
FLDATOUT:
Q

LASTAUTO.TEXT listed the contents of the disk DATOUT. This is done simply as an assurance that the user now has the disk DATOUT in the drive, and hence is ready for proper 2900 extraction.

3.5.2. Stream File for Multiple Device, Multiple Die Extraction

The 290 wafer test uses streamfiles to tie wafer movement together with measurement & analysis. This allows easy customization of the actual test procedure. For example, here is the conceptualization of the procedure to extract the CSIM paramters from devices on two separate sites on two different dies. If you want to actually try this example, start by setting the probes on the device subchip, on NMOS devices, at position x=29,y=10.

```
execute "measure"
                    Save output as outfil1.TEXT
                    Use CONTRL:anmosivds.TEXT to get drain at SMU1
                    Do it a single time
                    Use CONTRL:diemvl.TEXT to move to die on left
                    Do it a single time
                    Use CONTRL:diemvu.TEXT to move to die overhead
                    Do it a single time
                    Use CONTRL:mvleft.TEXT to move prober left one space
                    Do it twice
                    End after measurement
execute "measure"
                    Save output as outfil4.TEXT
                    Use CONTRL:dnmosivds.TEXT as control to get drain at SMU4
                    Do it a single time
                    End after measurement
execute "CMEAS"
                    device width = 5um
                    device length = 5um
                    Type of device (nmos[1], pmos[-1]) = 1
                    Threshold type (enhancement[1], zero[0], depletion[-1]) = 1
                    temp = 27
                    tox = 280
                    vddmax = 5 volts
                    input file = outfil1.TEXT
                    output file = reduc1.TEXT
execute "CMEAS"
                    device width = 20um
                    device length = 5um
                    Type of device (nmos[1], pmos[-1]) = 1
                    Threshold type (enhancement[1], zero[0], depletion[-1]) = 1
                    temp = 27
                    tox = 280
                    vddmax = 5 volts
                    input file = outfil4.TEXT
                    output file = reduc4.TEXT
execute "SSIM"
                    input file = reduc1.TEXT
                    output file = DATOUT:csimout1.TEXT
execute "SSIM"
                    input file = reduc4.TEXT
                    output file = DATOUT:csimout4.TEXT
```

The actual streamfile corresponding to this conceptualization is nearly a word for word translation. Note that the lines with single numeric entries are in response to the input prompting of executing code, and that they make more sense in the context of keyboard entry.

```
xmeasure
outfil1.TEXT
CONTRL:anmosivds.TEXT
1
CONTRL:diemvl.TEXT
1
CONTRL:diemvu.TEXT
1
CONTRL:mvleft.TEXT
2
end
xmeasure
outfil4.TEXT
CONTRL:dnmosivds.TEXT
1
end
xCMEAS
5
5
1
1
27
280
5
outfil1.TEXT
reduc1.TEXT
xCMEAS
20
5
1
1
27
280
5
outfil4.TEXT
reduc4.TEXT
xSSIM
reduc1.TEXT
DATOUT:csimout1.TEXT
xSSIM
reduc4.TEXT
DATOUT:csimout4.TEXT
```

4. Hints to using the 4145

The 4145 is fairly straightforward to use. Pages 3-85 through 3-110 of the Operations & Service Manual document its HPIB protocol. However, a few things were discovered which are not obvious from the documentation.

4.1. SMU's, VS's, and VM's

Each of the four SMU's (universal probe) can be defined for either voltage or current source. When defined as a voltage sweep, for instance, the current can be read back. Also, only *current* can be read back in this mode, since the 4145 apparently assumes that the voltage is already a known quantity.

On the other hand, the two VS's (voltage sources) cannot be part of the data output stream. There does not seem to be any way to either specify or send back the current that is drawn from these voltage sources directly. An indirect way might be to wire a structure between a VS and an SMU, define the SMU as a voltage source of 0 volts, & read the current through it. However, if the VS is referenced to ground, it cannot be current monitored.

4.2. Compliance

When specifying an SMU pin as a voltage or current source, the user also specifies a maximum current or maximum voltage to guard against shorts or opens, which could result from either a faulty device or user connection. Compliance errors can be noted by watching the 4145 screen for graphics or listing output. Additionally, the data received by the 9836 will contain a letter "C" or "T" for each measurement indicating compliance error, as opposed to the normal transmission which sends over the letter "N", so analysis software could check to halt on compliance error data.

Data Status Codes	
N	Normal
L	Interval Too Short
V	A/D Saturation
X	Oscillation
C	This Channel Compliance Error
T	Other Channel Compliance Error

However, when a VS is used either as a constant or swept source, the maximum current limit is automatically set at 10 mA, and as previously stated, if they are referenced to ground, there is no way to measure the current flowing from them. This has the result is that there is *no easy way to detect VS current limiting*. In a current limited situation, the voltage from the VS will simply fall in order to maintain the 10 mA max output, creating the definite possibility that the 4145 will send back faulty data, since there is no error code for VS current limiting.

4.3. Fixture Box

The user should be sure to disconnect the fixture box from the 4145 when it is not in use. There is an extra connector for the VS & VM probes that can be used instead of the BNC connectors, & if both are in place, it is as if someone had secretly placed a black box on all VS's & VM's. The classic situation is for the user to hook up the BNC's to a wafer test setup while neglecting to disconnect the extra connector to the test fixture box, & then spending a few hours trying to track down an error in the controlfiles or in the wafer itself.

4.4. Graphics

Color hardcopy of the 4145 curves may be obtained by connecting an HPIB plotter. The plotter must operate in the listen only mode, which means addressing it as #31. After a satisfactory plot has been obtained, usually by manipulating the the front panel buttons on the 4145 to zoom and/or autoscale, simply press the "PLOT" button located in the lower right hand corner on the 4145.

5. Hints to using the 2001x

The 2001x has some peculiarities, some which relate to its basic operation, others that make it a little strange to interface to HPIB. The operational peculiarities can be overcome, but are not explicitly documented in the manuals. Consequently, the next software upgrade for the 2001x (assuming that there is one), may cause incompatibilities with the present prober control files.

The HPIB peculiarities result from the way the 2001x wants to send back data. It is quite different from the 4145, and there are sections in "measure" where the program is a little awkward in order to make it compatible for both instruments.

5.1. Stage Movement

The 2001x requires that the user enter the die size in microns for both X & Y. When it receives stage movement commands over HPIB, it will then move the stage in units of die size. This makes it mentally difficult to test consecutive multiple sites on die since the user must then specify a "die" size that is really equal to the site size. In fact, the user can specify a die size of .01 microns, apparently for finest motion resolution. The minimum actual motion resolution, however, seems to be 2.5 microns.

There is no concept of relative motion; everything is absolute with respect to the last defined origin. If independent specification of X & Y coordinates were possible, given R x C sites on a die, the user would only have to specify R + C prober controlfiles in order to reach them all. However, only the upgraded 2001x ROMS supports this capability, not the currently-installed ROMS. In order to avoid ~ 350 stage movement files, four site move files are used that restablish the origin each time a movement is performed. This makes moving to the next die more complicated and requires that the tests be performed in a specific order, if minimum time is to be used for testing.

5.2. Receiving HPIB Commands & The Infamous MC

The 2001x contains a one-line buffer for HPIB commands, & apparently cannot execute them very fast. B.S.M. included a different format for writing out 2001x commands in "CSIM", where the NRFD line was polled. However, the HPIB protocol for the Pascal command "writestrngln" checks this line automatically, so "measure" uses the same procedure to write commands out to the 2001x as it uses for the 4145.

After each stage movement, the 2001x will activate the SRQ line. This is the signal that it wants to send back data regarding the success of the movement. Unfortunately, this signal is quite different from that of the 4145. The 4145 will raise a bit in the HPIB status register when it has data. The solution was to look for SRQ if data taking is disabled, and look at the statusbyte if data is expected to be stored.

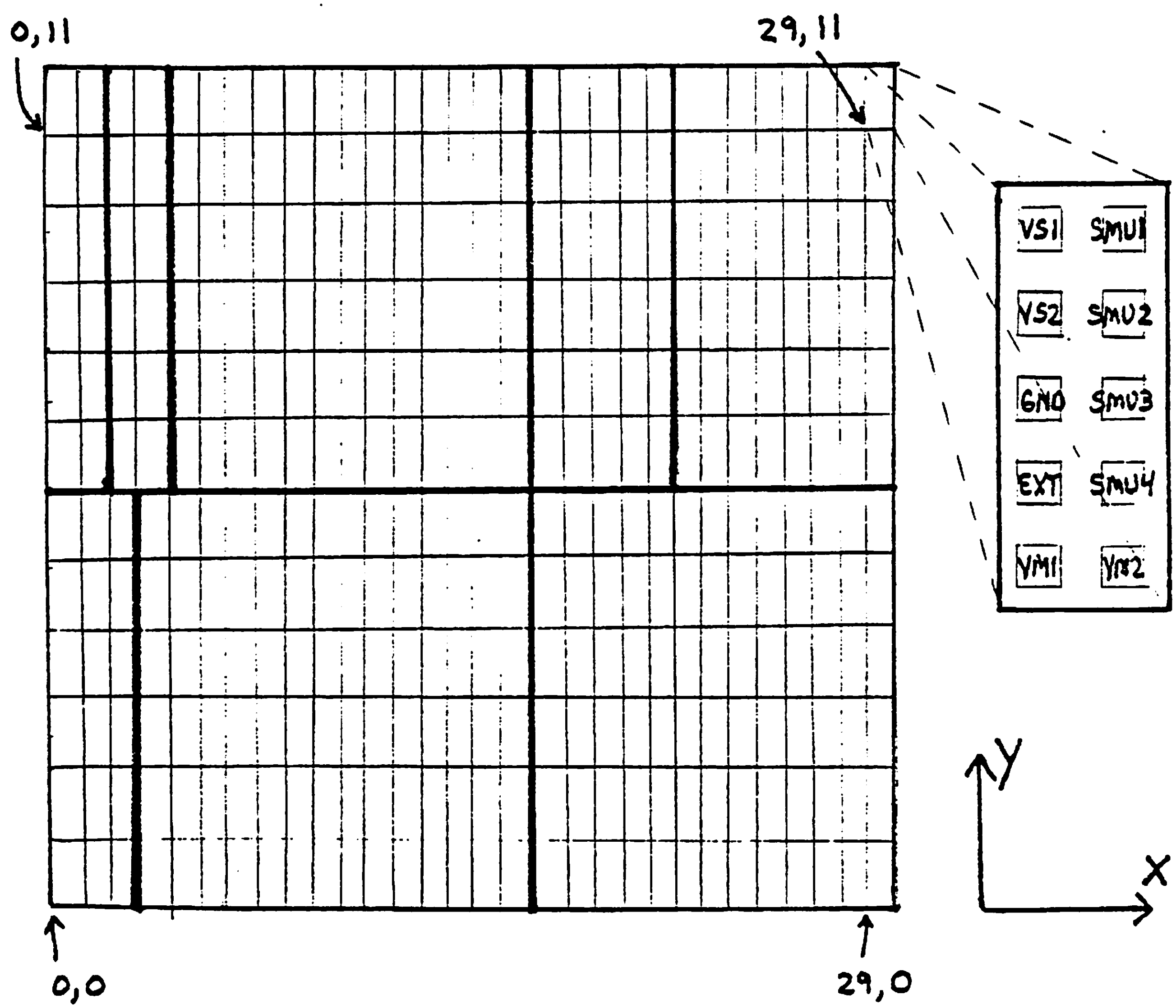
After the 9836 senses the SRQ line, it must do a serial poll of the 2001x before the 2001x will receive any more commands. If the 2001x was successful in completing its stage movement, it will want to send back the letters "MC" followed by carriage-return & line-feed. If the currently active HPIB controller does not allow the 2001x to become the talker, the 2001x will re-enable HPIB command reception after 5 seconds as long as it received its serial poll. This means if the 9836 ignores the 2001x once serial poll is performed, the stage cannot be not moved more than once every 5 seconds, Luckily, the routine for getting back 4145 data can be used to pick up these characters from the 2001x. These characters are simply dropped since "data back" should be set false in the controlfile.

APPENDIX 1

Coordinates of 290 Chip for Probing with 2X10 Card.

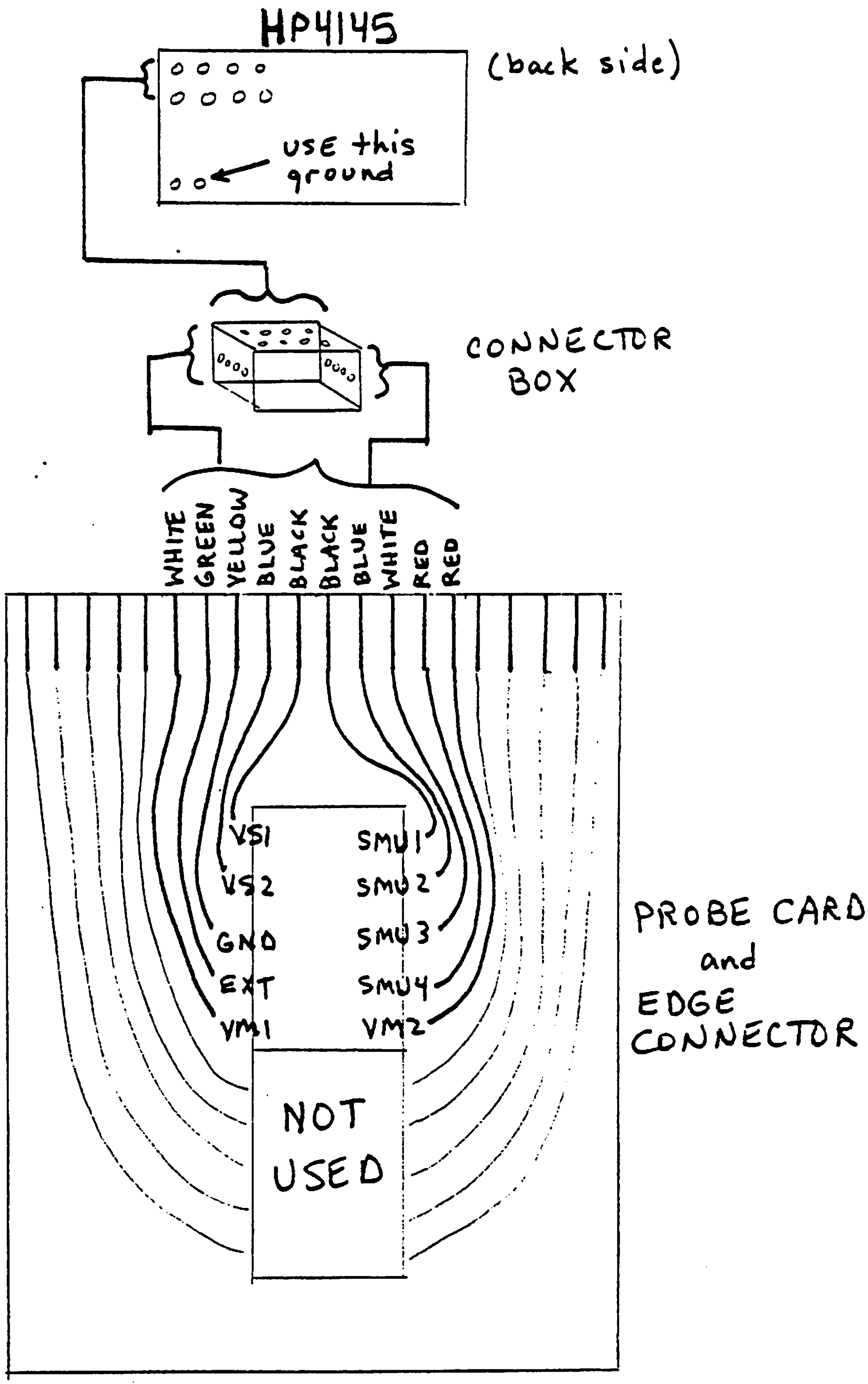
The 290 die is shown below. It is probed with a 2X10 probe card. Only the top 2X5 probes are used for probing, since the HP9836 has 8 input/outputs, plus a ground, and an external source supplies by the user, which adds up to 10. (The bottom half could just as easily be used.)

The 290 wafer contains 30 columns X 12 rows of 2X5 probe locations. These locations are numbered from 0 to 29, and 0 to 11 respectively as shown on this map.



APPENDIX 2

2X 10 Probe Card and Connection to HP4145



APPENDIX 3

HPIB Command Summary for HP4145 and Electroglas 2001x.

The following pages are copied from the Electorglas 2001x I/O manual and the HP4145 Users Manual. It contains the HPIB instreuctions, which are placed on the HPIB Bus, used to control the setup and movement of the 2001x, and the setup and measurement of the HP4145.

3-105. Remote Program Codes and Parameter Setting

3-106. Figure 3-39 shows the available remote program codes and parameter settings. Program codes are divided into three categories : (1) System Mode program codes, (2) User Mode program codes, and (3) program codes common to both modes. User functions, OUTPUT SEQUENCE, PURGE, REPACK, DISC COPY, and HEAD CLEAN can not be programmed.

Programming notes :

1. Numeric values can be entered in fixed decimal format or floating decimal format. (max. 12 char and max. 2 digits exponent.)

   Example : Fixed decimal : 25.32
   Floating decimal : 2.532E+01

2. Voltage (V), current (A), and time (s) units are not required when entering numeric values.
3. Terminator (; or CR or LF) is required at the end of each parameter setting on a program line. In the examples given below, (TERM) represents the terminator.
4. Channel names must be enclosed in apostrophes (' ').

SYSTEM MODE PROGRAM CODES

Following program codes are used when the 4145A is set to System Mode.

Direct Paging (to change page) :

DE : CHANNEL DEFINITION Page
SS : SOURCE SETUP Page
SM : MEAS & DISP MODE SETUP Page
MD : Display Page (page selected for DISPLAY MODE)
US : User Mode

Notes

1. When the 4145A receives a Direct Paging command, it checks the setup on the displayed page before proceeding to the specified page. If an illegal setup is detected, an error message will be displayed, the SRQ bit will be turned on, and the page will not be changed.
2. Display returns to the MENU page when the 4145A receives a Device Clear command.

Figure 3-39. Remote Program Codes and Parameter Setting (Sheet 1 of 9).

CHANNEL DEFINITION Page (program code "DE")

Setup for SMUs 1 through 4

```
CH N* , 'XXXXXX' , 'XXXXXX' , N , N(TERM)
  (1)     (2)        (3)      (4)  (5)
```

(1) SMU channel number (1 - 4)
(2) V NAME (up to 6 characters)
(3) I NAME (up to 6 characters)
(4) SOURCE MODE (1 - 3)
  1 : V
  2 : I
  3 : COM**
(5) SOURCE FUNCTION (1 - 4)
  1 : VAR1
  2 : VAR2
  3 : CONST
  4 : VAR1'

* If nothing is specified after the channel number, the channel is turned off (NOT USE).

** When SOURCE MODE is set to 3 (COM), SOURCE FUNCTION must be set to 3 (CONST).

Setup for Vs1 and Vs2

```
VS N* , 'XXXXXX' , N(TERM)
  (1)     (2)      (3)
```

(1) Vs channel number (1 or 2)
(2) V NAME (up to 6 characters)
(3) SOURCE FUNCTION (1 - 4)
  1 : VAR1
  2 : VAR2
  3 : CONST
  4 : VAR1'

* If nothing is specified after the channel number, the channel is turned off (NOT USE).

Setup for Vm1 and Vm2

```
VM N* , 'XXXXXX'(TERM)
  (1)     (2)
```

(1) Vm channel number (1 or 2)
(2) V NAME (up to 6 characters)

* If nothing is specified after the channel number, the channel is turned off (NOT USE).

Figure 3-39. Remote Program Codes and Parameter Setting (Sheet 2 of 9).

SOURCE SETUP Page (program code "SS")

Setup for VAR1

```
XX  N  ,  ±NN.NNN ,  ±N.NNNN ,  N.NNNN ,  N.NNN(TERM)
(1) (2)     (3)        (4)        (5)       (6)
```

(1) SOURCE MODE of VAR1 (VR or IR)
 VR : Voltage Source
 IR : Current Source
(2) SWEEP MODE (1 - 4)
 1 : LINEAR
 2 : LOG 10
 3 : LOG 25
 4 : LOG 50
(3) START value
(4) STOP value
(5) STEP value*
(6) COMPLIANCE value

* If SWEEP MODE (2) is set to 2, 3, or 4, omit STEP (5).

Setup for VAR2

```
XX  ±N.NNNN ,  ±N.NNNN ,  NN ,  N.NNN(TERM)
(1)   (2)        (3)      (4)     (5)
```

(1) SOURCE MODE or the VAR2 (VP or IP)
 VP : Voltage Source
 IP : Current Source
(2) START value
(3) STEP value
(4) Number of steps
(5) COMPLIANCE value

Setup for CONSTANT SMUs

```
XX  N  ,  ±N.NNNN ,  N.NNNN(TERM)
(1) (2)     (3)        (4)
```

(1) SOURCE MODE of the channel (VC or IC)
 VC : Voltage Source
 IC : Current Source
(2) SMU channel number (1 - 4)
(3) Output value
(4) COMPLIANCE value

Setup for CONSTANT Vs

```
SC  N  ,  ±N.NNNN(TERM)
   (1)      (2)
```

(1) Vs channel number (1 or 2)
(2) Output value

Figure 3-39. Remote Program Codes and Parameter Setting (Sheet 3 of 9).

HOLD TIME Setting

HT N.NN(TERM)
(1)

(1) HOLD TIME

DELAY TIME Setting

DT N.NN(TERM)
(1)

(1) DELAY TIME

VAR1' RATIO/OFFSET Setting

XX ±N.NN(TERM)
(1) (2)

(1) RATIO/OFFSET (RT or FS)
RT: RATIO
FS: OFFSET
(2) Value

MEAS & DISP MODE SETUP Page (program code "SM")

Time Domain Measurement Setup (only when VAR1 is not selected on the CHANNEL DEFINITION page)

WAIT TIME Setting

WT N.NNN(TERM)
(1)

(1) WAIT TIME

INTERVAL Setting

IN N.NN(TERM)
(1)

(1) INTERVAL Time

NO. OF RDNGS Setting

NR NNN(TERM)
(1)

(1) No. of Readings

DISPLAY MODE Selection
DM1: GRAPHICS
DM2: LIST
DM3: MATRIX
DM4: SCHMOO

Figure 3-39. Remote Program Codes and Parameter Setting (Sheet 4 of 9).

Setup for GRAPHICS mode ("DM1")

XX 'XXXXXX', N, ±N.NNN, ±N.NNN(TERM)
(1) (2) (3) (4) (5)

(1) AXES
- XN : X axis
- YA : Y1 axis
- YB : Y2 axis*
- XT : X axis for time domain measurement**

(2) Monitor channel NAME for the specified axis (must be one of the monitor channel names specified on the CHANNEL DEFINITION page).
(3) SCALE 1 : LINEAR 2 : LOG
(4) MIN value
(5) MAX value

* Y2 axis is optional.
** For time domain measurements, (2) and (3) should be omitted.

Setup for LIST mode ("DM2")

LI 'XXXXXX', 'XXXXXX', 'XXXXXX', 'XXXXXX', 'XXXXXX', 'XXXXXX'(TERM)
(1) (2) (3) (4) (5) (6)

(1) ~ (6) Monitor channel NAMES. At least one NAME must be specified (must be the monitor channel names specified on the CHANNEL DEFINITION page).

Setup for MATRIX mode ("DM3")

MX 'XXXXXX'(TERM)
(1)

(1) Monitor channel NAME (must be one of the monitor channel names specified on the CHANNEL DEFINITION page).

Setup for SCHMOO mode ("DM4")

SH 'XXXXXX', ±NN.NN, ±NN.NNN, ±N.NNNN, ±N.NNNN(TERM)
(1) (2) (3) (4) (5)

(1) Monitor channel NAME (must be one of the monitor channel names specified on the CHANNEL DEFINITION page).
(2) Minimum value for "M"
(3) Minimum value for "Δ"
(4) Minimum value for "+"
(5) Minimum value for ":"

* If no minimum value is specified for (2), (3), (4), or (5), the corresponding symbol will not be used in the SCHMOO PLOT. A comma (,) must be entered, however.

MEASUREMENT Codes (program code "MD")
- ME1 : SINGLE*
- ME2 : REPEAT
- ME3 : APPEND
- ME4 : STOP

* The GET (Get Execute Trigger) command can be used in place of the ME1 program code. An example of the GET command is the TRIGGER command on the 85A or 9845A.

Figure 3-39. Remote Program Codes and Parameter Setting (Sheet 5 of 9).

Following progam codes are valid on any page.

AUTO SEQ codes

AS1 : START
AS2 : CONTINUE
AS3 : STOP

SAVE Function

SV 'X (1) _ (2) XXXX (3) _ (4) XXXXXX' (5) (TERM)

(1) File type
- P : Program file
- D : Program/Data file
- S : ASP file

(2) Space
(3) File name (up to 6 characters)
(4) Space
(5) Comment (up to 8 characters)

* (4) and (5) are optional.

GET Function

GT 'X (1) _ (2) XXXX' (3) (TERM)

(1) File type
(2) Space
(3) File name

Assignment of Data Output Channel

DO 'XXXXX' (1)

(1) Monitor channel NAME (must be one of the monitor channel names specified on the CHANNEL DEFINITION page).

PRINT Function

PR : PRINT function ON*
PF : PRINT function OFF

* Refer to paragraph 3-129 for instructions covering HP-IB controlled plot operations.

Graphics Language (GL1) Mode (only on the GRAPHICS PLOT Page)

GL1 : Graphics Display mode ON
GL0 : Graphics Display mode OFF

Figure 3-39. Remote Program Codes and Parameter Setting (Sheet 6 of 9).

3.0 COMMAND SET

3.1 SETUP PARAMETERS

Setup parameters are used prior to action commands to establish die size, Z limits, matrix dimensions, wafer diameter, coordinate type (English/Metric), coordinate preset, random-probe (learn) list, and to enable or disable various operational modes.

3.1.1 SP, Set Parameter

General set parameter command. General form is:

SPll<parameter string>

where ll is max 2 digit line number. Specific forms are as follows:

3.1.1.1 SP1, Set Die Size

Set unit of X, Y die size in units of 0.1 mil or 1 micron.

SP1XxxxxxxYyyyyyy

Example: SP1X1234Y5678 sets X die to 123.4 mils (or 1.2325 mm) and Y die to 567.8 mils (or 5.6775 mm).

3.1.1.2 SP2, Set Preset

Die coordinate to be assigned to starting die.

SP2XxxxxxxYyyyyyy

Example: SP2X50Y-50 sets starting die coordinate value to X=50 and Y=-50

3.1.1.3 SP3, Set Matrix Size.

Set number of rows and columns in matrix probe pattern.

SP3X100Y48 will establish a pattern of 100 columns and 48 rows to be probed if the matrix probe pattern is selected.

3.1.1.4 SP4, Set Wafer Diameter

Set diameter of wafer to be probed, in mm. Used for all prober functions requiring knowledge of wafer diameter.

SP4D125 will establish the wafer diameter as 125 mm.

3.1.1.5 SP5, Set Z Overtravel

Set amount of added Z travel after sensor contact is established. Used when edge sensor is enabled. Units are 0.1 mil (but resolution depends on the chuck gear).

SP5Zzzzz

Example: SP5Z36 will set the Z overtravel parameter to 3.5 mils.

3.1.1.6 SP6, Set Z Clearance

Set amount of added Z travel after sensor non-contact is established. Used when edge sensor is enabled or in non-contact edge sense mode. Units are 0.1 mil.

SP6Zzzzz

Example: SP6Z100 will set the Z clearance parameter to 10.0 mils.

3.1.1.7 SP7, Set Z Up Limit

Set absolute position of upper limit of Z travel. It is used as a safety limit when the edge sensor is enabled. When the edge sensor is not enabled it is used as the Z "up" position.

SP7Zzzzz

Example: SP7Z2800 will set the maximum Z up position to 280.0 mils above the reference "0" position.

3.1.1.8 SP8, Set Z Down Limit

Set absolute position of lower limit of Z travel. It is used as a safety limit when the edge sensor is enabled. When the edge sensor is not enabled it is used as the Z "down" position.

SP8Zzzzz

Example: SP8Z2000 will set the minimum Z down position to 200.0 mils above the reference "0" position.

3.1.1.9 SP9, Set Z Align Height

Used to set the height for proper focus under the auto align subsystem optics.

SP9Zzzzz

Example: SP9Z2850 sets the focus height to 285.0 mils above the reference "0" position.

3.1.1.10 SP11, Set Inker Delay

Used to allow inking outside the probe area. Delay may be set to ink 1 or 2 die behind. Delay=0 means in-place inking. If delay is set, then inkers are actuated as follows:

Bincode	X-Coordinate	Inker
0		none
1	increasing	1
2	increasing	1
1	decreasing	2
2	decreasing	2
4	increasing	3
8	increasing	3
4	decreasing	4
8	decreasing	4

SP11Dd

Example: SP11D2 will result in inking 2 places behind. Inkers should be placed 2 places to the left and to the right of the probe location.

3.1.1.11 SP12, Set Z-Scale Value

Used to set the Z-resolution according to the chuck option. Units are steps per mil (2 for a standard chuck option with 0.5 mils per step).

SP12Sss

Example: SP12S2 sets the Z-scale value to the standard Z-resolution of 0.5 mils.

3.1.1.12 SP13, Set Turn Around

This parameter is used to set the number of off-wafer steps needed, in edge-sense mode, to turn around. Range is 0 to 8.

SP13Tt

Example: SP13T4 prober will turn around after 4 wafer steps in X.

3.1.1.13 SP14, Set Reprobe Limit

A non-zero value will enable the re-probe function.

After the specified number of consecutive "bad" dies tested, the prober will position to the last tested "good" die and re-test it. If the previously good die now tests bad, the prober will stop with an error message. If it tests good, probing will resume with the next die to be tested.

SP14Rrrrrr

Example: SP14R100 will set the reprobe limit to 100.

3.1.1.14 SP15, Set Maximum Row Counter

Used to limit the number of rows probed in circular probe mode.

Example: SP15M51 will terminate circular probe after 51 rows probed.

3.1.2 SM, Set Mode

General set mode command. General form is:

SMll<mode value>

where ll is max 2 digit line number. Specific forms are as follows:

3.1.2.1 SM1, Set Unit

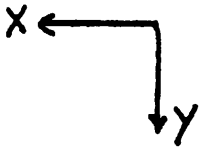
Used to set XY coordinate unit of measure to English or Metric.

SM1U0 sets system to English.

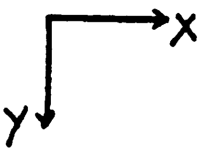
SM1U1 sets system to Metric.

3.1.2.2 SM2, Set Quadrant

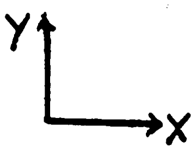
Used to set starting quadrant and orientation of die coordinate system as follows:



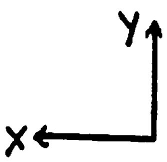
SM2Q1 indicates that Quadrant I (upper right) will be starting die. X coordinates will increase to the left across the wafer; Y coordinates will increase toward the bottom of the wafer.



SM2Q2 indicates that Quadrant II (upper left) will be the starting die. X coordinates will increase to the right across the wafer while Y coordinates will increase toward the bottom of the wafer.



SM2Q3 indicates that Quadrant III (lower left) will be the starting die. X coordinates will increase to the right across the wafer while Y coordinates will increase toward the top.



SM2Q4 indicates that Quadrant IV (lower right) will be the starting die. X coordinates will increase to the left across the wafer while Y coordinates will increase toward the top.

3.1.2.3 SM3, Flat Select

Used to select the orientation of the wafer major flat and is the range from 0-359 degrees:

SM3F0 will orient the major flat to the 6 o'clock position.

SM3F90 will orient the major flat to the 9 o'clock position.

SM3F180 will orient the major flat to the 12 o'clock position.

SM3F270 will orient the major flat to the 3 o'clock position.

3.1.2.4 SM4, Autoprobe Mode select

Used to select autoprobe function as follows:

SM4P0 will deselect current autoprobe function.

SM4P1 will select edge sense function.

SM4P2 will select matrix probe probe function.

SM4P3 will select circular probe function.

SM4P4 will select random-access probe function.

3.1.2.5 SM5, Edge Sensor Enable

Used to enable or disable use of edge sensor for establishing Z position. When disabled, Z travel is between Z upper and lower limits established by operator input or external I/O functions SP7 and SP8.

SM5E0 disables edge sensor.

SM5E1 enables edge sensor.

3.1.2.6 SM6, Skipdie Enable

Used to enable or disable "skipdie" function. When enabled, the "learn" list is used to designate dies to be skipped during testing. This mode is valid only for autoprobe functions 1-3.

SM6S0 disables skipdie function.

SM6S1 enables skipdie function.

3.1.2.7 SM7, Log Error Messages Enable

Used to enable or disable print out of certain error messages on the log printer.

SM7E0 disables error logging

SM7E1 enables error logging

3.1.2.8 SM8, Wafer Map Enable

Used to enable or disable a wafer map print out after pattern is completed.

SM8M0 disables wafer map print out

MS8M1 enables wafer map print out

3.1.2.9 SM9, Cassette Map Enable

Used to enable or disable a cassette map print out after cassette is completed.

SM9M0 disables cassette map print out

SM9M1 enables cassette map print out

3.1.2.10 SM10, Edge Inking Enable

Used to enable or disable wafer edge inking.

SM10E0

SM10E1

3.1.3 Miscellaneous Set Up Parameters

The following additional parameter entry commands are recognized:

3.1.3.1 WM, Enable Wafer Map

Used to enable or disable XY coordinate output in teststart message during autoprobe. When wafer map is enabled, the teststart message appears in the form TSXxxxxxxYyyyyyy. If wafer map is disabled, only TS is output.

WM0 disables wafer map

WM1 enables wafer map

3.1.3.2 RS, Reset Learn List

The "learn" list is used for random-access probing or to designate skipped dies if the skipdie function is enabled. RS is used to null the list.

3.1.3.3 AD, Add Point to Learn List

This function is used to add coordinate points to the "learn list". Coordinate values are die coordinates. Up to 128 coordinate points may be in the learn list.

ADXxxxxxxYyyyyyy

Example: ADX50Y9999 will add the point X=50, Y=9999 to the "learn list".

3.1.3.4 DE, Delete Point from Learn List

This function is used to delete coordinate points from the "learn list". The list is searched for the referenced coordinate pair. Only the first "hit" is deleted from the list.

DEXxxxxxxYyyyyyy

Example: DEX1Y24 will delete the first occurence of the point X=1, Y=24 from the "learn list".

3.1.3.5 RD, Change Device Type

This function allow to change the I/O character device type string used on the log printer.

Example: RDABCDE will set the device type to ABCDE.

3.1.3.6 RL, Change Lot Number

Similar to 3.1.3.5 except used for changing the lot number.

3.2 ACTION COMMANDS

3.2.1 MO, Move XY

This command is used to move the XY positioner.

MOXxxxxxYyyyyy

where X and y values are absolute die coordinate values, in units of die size. If the chuck is up prior to motion, it is lowered, then raised again after XY motion is complete. When motion is complete and the chuck has been restored to its previous position, the message MC is sent to the host.

Example: MOX235Y-922 results in a motion to a position X=235, Y=-922 with respect to the origin. Motions attempted to positions beyond the table area will be truncated.

3.2.2 ZU, Raise Chuck

This command is used to raise the chuck. The chuck moves only if the present state is "down". The actual level the chuck reaches depends on whether the edge sensor is used.

ZU results in the chuck being raised.

3.2.3 ZD, Lower Chuck

This command is used to lower the chuck. The chuck moves only if the present state is "up". The actual level the chuck reaches depends on whether the edge sensor is used.

ZD results in the chuck being lowered.

3.2.4 HO, Move to Home Position

This command moves the positioner to the manual load/unload area and would be typically used to allow the operator to transfer a wafer.

HO results in positioner motion to the home position.

3.2.5 ME, Message to Operator

This command is used to present a message on the last two lines of the console display device. Up to 64 characters may be displayed. The "bell" character may be included anywhere in the message string and will result in an audible "beep" accompanying the message.

ME<message string--up to 64 characters>

Example: MEABCDEFG will display the string "ABCDEFG" on line 14 of the console display device.

3.2.6 AA, Auto Align

This command allows the host computer to start the auto alignment procedure. Note: Reference has to be stored prior to this command, otherwise the prober will not execute the command.

AA results in wafer being aligned.

Note: "MC" will be returned if alignment is properly done.

"MF" will be returned, if alignment failed.

3.2.7 AP, Abort Probing

This command stops probing immediately and does the same as PAUSE key.

AP causes probing to pause.

3.2.8 LO, Load Wafer

Used to load a new wafer from the cassette. If there is a wafer on the chuck, it first unloads this wafer. "LO" command is exactly like the LOAD key.

LO results in wafer on chuck being unloaded (if there is one) and the next wafer being loaded.

Note: "MC" of "MF" is returned after load is completed or failed.

3.2.9 PR, Probe Wafer

This command starts probing one wafer, like the AUTO PROBE key, with autoload or auto align disabled.

3.2.10 CB, Clear Log Buffers

"CB" is used to clear the wafer log buffer and the cassette log buffer.

3.2.11 LP, Print Log Data

These commands print out a wafer map or a cassette map at any time and do not modify the log data.

LP0 results in printing out a wafer map

LP1 results in printing out a cassette map.

Note: "MC" will be returned after print out is done.

3.3 STATUS COMMANDS

3.3.1 ?S, Query Prober Status

The status of the prober is returned in the form:

SZ(U,D)W(0,1)C(0,1)

where:

- Z is chuck position,
  - U=up
  - D=down
- W indicates wafer on chuck,
  - 0=off
  - 1=on
- C indicates edge sensor status
  - 0=no contact
  - 1=contact

Example: ?S results in status report of SZUW1C0. This means chuck is up, wafer is on chuck, no edge sensor contact was sensed.

3.3.2 ?P, Query Current Position

This command is used to determine the current position of the XY positioner, die coordinates, absolute with respect to the current origin. ?P results in a report in the following form:

XxxxxxxYyyyyyy

where the X and Y values are absolute die coordinate position with respect to the current origin.

Example: ?P results in reply X1235Y0 which means that the current position is X=1235, Y=0 with respect to the current origin.

3.4 AUTOPROBE COMMANDS

3.4.1 SM4, Autoprobe Mode Select

SM4, Autoprobe Mode Select

This command is described in 3.1.2.4 and is used to select the autoprobe function which will be invoked when the operator presses the AUOTPROBE key or with command "PR" as described in 3.2.9.

3.4.2 TC, Signal Test Complete

This command is used to signal completion of test on current die and to actuate one or more inkers, if enabled.

TCb

where b is a single character "bin" code. If used for inking the following codes are used:

Code	Inker(s)
0	none
1	1
2	2
4	3
8	4
3	1,2
5	1,3
9	1,4
6	2,3
:	2,4
<	3,4
7	1,2,3
;	1,2,4
=	1,3,4
>	2,3,4
?	1,2,3,4

The prober will then index to the next die in the pattern and transmit the teststart message.

3.4.3 WM, Enable Wafer Map

See paragraph 3.1.3.1

4.0 MESSAGES

The following messages are sent to the host:

4.1 Status Reply

The reply to command ?S, Query Status is described in paragraph 3.3.1.

4.2 Position Reply

The reply to command ?P, Query Position is described in paragraph 3.3.2.

4.3 Command Complete or Command Fail

Completion of certain commands is signaled to the host with the following message:

MC means command has been correctly completed.

MF means command failed.

4.4 Test Start

This message is transmitted first after the operator presses the AUTOPROBE switch and the chuck is raised to contact the first die to be probed. Each time the host sends the Test Complete message (paragraph 3.4.2) the prober indexes to the next die in the pattern, raises the chuck and transmits the Test Start message. After the last die has been probed, the Pattern Complete message is sent.

The test start message is sent in two forms:

TS

This form is used when the Wafer Map function is disabled.

TSXxxxxxYyyyyyy

This form is used when the Wafer Map function is enabled.

Example: Wafer Map function is enabled, the Test Complete message has been received by the prober. The prober indexes to the next position in the pattern, which is X=1, Y-24. The message sent to the host is:

....

4.5 Pattern Complete Message

After the Test Complete message has been received by the prober for the last die in the pattern, the following message is transmitted to the host:

PC

4.6 Test Complete Message

If the Test Complete signal is received on the "user" interface, the bin code is accepted from the "user" interface and used for inking, if inkers are enabled. It is then sent to the host in the test complete message:

TCb

where b is a single character representing the bin code received from the "user" interface. This character is encoded the same way it would be if the Test Complete command were received from the host. See paragraph 3.4.2.

Please note that this message is not sent in response to the TC command from the host; it is sent only in response to Test Complete signal from the "user" interface.

5.0 MESSAGE FORMAT AND PROTOCOL

5.1 Message Format and Coding

All message strings are the valid command groups described above, coded in 8-bit ASCII. Bit 8 is ignored. Message strings are terminated by line feed (hex 0A) characters. Carriage return characters (hex 0D) are ignored.

Messages sent to the host are 8-bit ASCII with bit 8 = 0 and are terminated by carriage return followed by line feed. On the IEEE-488 port, the EOI signal is asserted with the line feed character.

5.2 Protocol

Messages sent to the prober are buffered one line at a time, but in general cannot be processed as quickly as they might be sent. To prevent data overrun, a simple protocol is used to signal readiness for input.

For the IEEE-488 port, this is done by asserting the NRFD signal until the interface is ready to receive.

For the serial port, this consists of the single character message ">" (plus carriage return and line feed). In addition, the RS232-C signal clear-to-send (CTS) is asserted whenever the interface is ready for data. The host may prevent data transmission from the prober by negating the data-terminal-ready (DTR) signal. This immediately turns off the transmitter, and will result in a garbled messge if used mid-transmission. It should only be negated immediately following reception of the line feed character from the prober. See also the section on the physical interface. (Paragraph 6.0)

Message transmission from the prober on the IEEE-488 interface is done by asserting the SRQ signal. The host must service this by performing a serial poll. The host has 5 seconds within which to address the prober as "talker" and accept the message. If this is not complete within 5 seconds, the prober will abort the message transmission. The SRQ function may be defeated by setting switch SW1-8 on the Tester Interface Board to the "on" position. If this is done, the prober passively waits for the host to address it as "talker". The 5 second timeout applies to this mode of operation as well.

6.0 PHYSICAL CONNECTION

6.1 RS-232 SIGNALS

Serial interface signals are available at the connector marked "SERIAL INTERFACE" on the rear panel of the power control module. The connector is a female 25 pin "D" connector and the available signals are tabulated as follows:

APPENDIX 4

Listing of Control Files

The following are control files used by the program "measure". They have been divided up into those for control of the 2001x prober and for measurment using the HP4145.

Electroglas 2001x

filename	purpose
prbsetup.TEXT	sets up 0,0 origin as lower left corner of die
diemvl.TEXT	moves the prober one DIE to left
diemvr.TEXT	moves the prober one DIE to right
diemvu.TEXT	moves the prober one DIE up
diemvd.TEXT	moves the prober one DIE down
mvleft.TEXT	moves the prober one 2X5 location to left
mvright.TEXT	moves the prober one 2X5 location to right
mvup.TEXT	moves the prober one 2X5 location up
mvdown.TEXT	moves the prober one 2X5 location down

HP4145

filename	subchip	location	purpose
anmosivds.TEXT	device	26,10 thru 29,11	NMOS Ids-Vds curves-drain at SMU1
bnmosivds.TEXT	device	26,10 thru 29,11	NMOS Ids-Vds curves-drain at SMU2
cnmosivds.TEXT	device	26,10 thru 29,11	NMOS Ids-Vds curves-drain at SMU3
dnmosivds.TEXT	device	26,10 thru 29,11	NMOS Ids-Vds curves-drain at SMU4
apmosivds.TEXT	device	22,10 thru 25,11	PMOS Ids-Vds curves-drain at SMU1
bpmosivds.TEXT	device	22,10 thru 25,11	PMOS Ids-Vds curves-drain at SMU2

cpmosivds.TEXT	device	22,10 thru 25,11	PMOS Ids-Vds curves-drain at SMU3
dpmosivds.TEXT	device	22,10 thru 25,11	PMOS Ids-Vds curves-drain at SMU4
anmosivgs.TEXT	device	26,10 thru 29,10	NMOS Ids-Vgs curves-drain at SMU1
bnmosivgs.TEXT	device	26,10 thru 29,10	NMOS Ids-Vgs curves-drain at SMU2
cnmosivgs.TEXT	device	26,10 thru 29,10	NMOS Ids-Vgs curves-drain at SMU3
dnmosivgs.TEXT	device	26,10 thru 29,10	NMOS Ids-Vgs curves-drain at SMU4
apmosivgs.TEXT	device	22,10 thru 25,11	PMOS Ids-Vgs curves-drain at SMU1
bpmosivgs.TEXT	device	22,10 thru 25,11	PMOS Ids-Vgs curves-drain at SMU2
cpmosivgs.TEXT	device	22,10 thru 25,11	PMOS Ids-Vgs curves-drain at SMU3
dpmosivgs.TEXT	device	22,10 thru 25,11	PMOS Ids-Vgs curves-drain at SMU4
nfield.TEXT	device	28,10 thru 29,11	All 4 Field NMOS Ids-Vgs curves at a single 2X5 location
nfield1.TEXT	device	28,10 thru 29,11	Field NMOS Ids-Vgs curves-drain at SMU1
nfield2.TEXT	device	28,10 thru 29,11	Field NMOS Ids-Vgs curves-drain at SMU2
nfield3.TEXT	device	28,10 thru 29,11	Field NMOS Ids-Vgs curves-drain at SMU3
nfield4.TEXT	device	28,10 thru 29,11	Field NMOS Ids-Vgs curves-drain at SMU4
pfield.TEXT	device	26,10 thru 27,11	All 4 Field PMOS Ids-Vgs curves at a single 2X5 location
pfield1.TEXT	device	26,10 thru 27,11	Field PMOS Ids-Vgs curves-drain at SMU1

pfield2.TEXT	device	26,10 thru 27,11	Field PMOS Ids-Vgs curves-drain at SMU2
pfield3.TEXT	device	26,10 thru 27,11	Field PMOS Ids-Vgs curves-drain at SMU3
pfield4.TEXT	device	26,10 thru 27,11	Field PMOS Ids-Vgs curves-drain at SMU4
nssimsmu1.TEXT	device	26,10 thru 29,11	SPICE-CSIM parameter extraction NMOS-drain at SMU1
nssimsmu2.TEXT	device	26,10 thru 29,11	SPICE-CSIM parameter extraction NMOS-drain at SMU2
nssimsmu3.TEXT	device	26,10 thru 29,11	SPICE-CSIM parameter extraction NMOS-drain at SMU3
nssimsmu4.TEXT	device	26,10 thru 29,11	SPICE-CSIM parameter extraction NMOS-drain at SMU4
pssimsmu1.TEXT	device	22,10 thru 25,11	SPICE-CSIM parameter extraction PMOS-drain at SMU1
pssimsmu2.TEXT	device	22,10 thru 25,11	SPICE-CSIM parameter extraction PMOS-drain at SMU2
pssimsmu3.TEXT	device	22,10 thru 25,11	SPICE-CSIM parameter extraction PMOS-drain at SMU3
pssimsmu4.TEXT	device	22,10 thru 25,11	SPICE-CSIM parameter extraction PMOS-drain at SMU4
meandor.TEXT	process dropin	0,10	I-V measurement of 2 meandor resistors
cchain.TEXT	process dropin	0,8 1,8 1,10	contact chain,Van der Pauw, & linewidth

APPENDIX 5

Listing of Stream Files

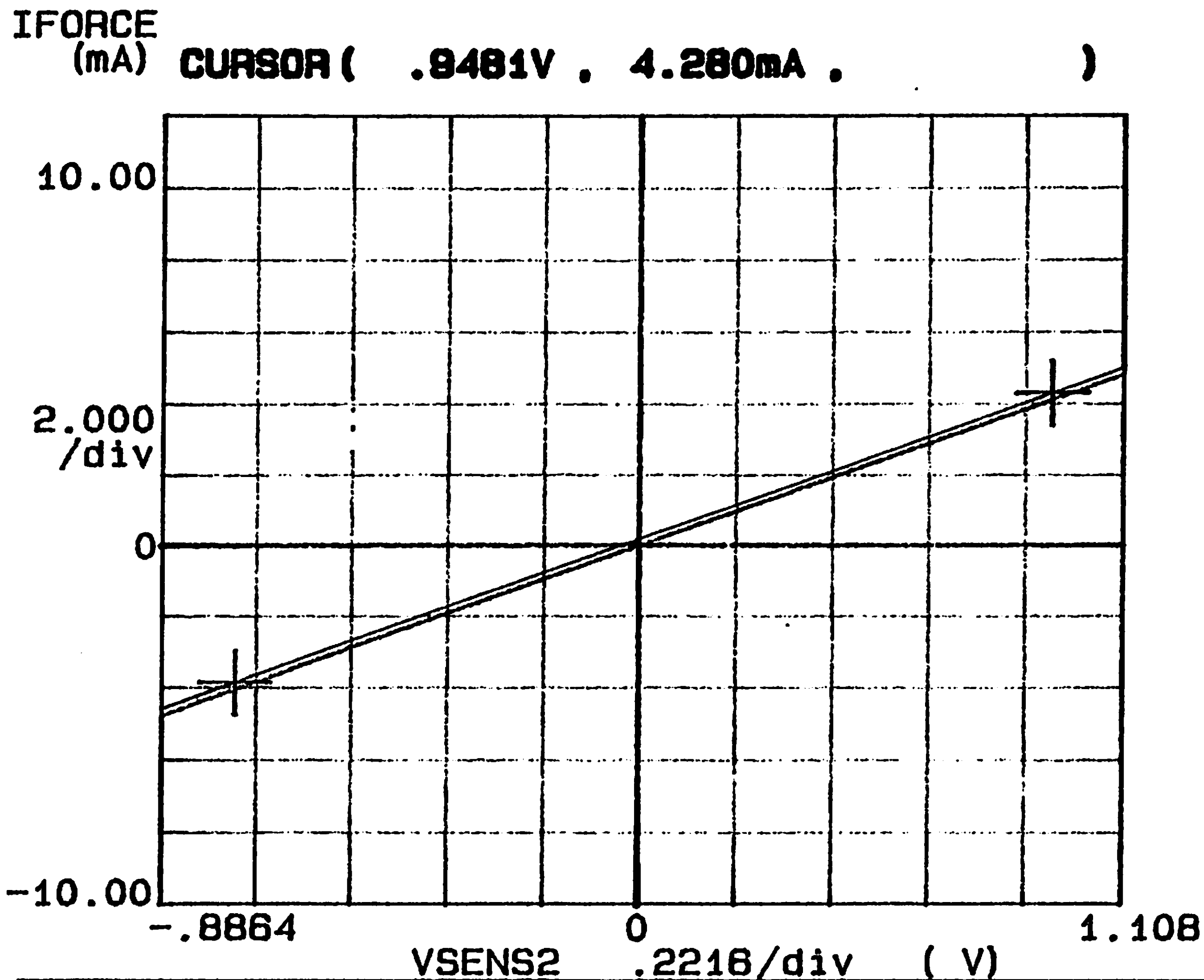
The following are stream files used by the Pascal operating system. Some of them call movement control files, hence they must be used only in specific places (i.e. in the examples given in the writeup)

All stream and control files are located on floppy disk **CONTRL:**. and all output files are placed on floppy disk **DATOUT:**. The only exception to this is when the files are used only as intermediate files, for example, running "cmeas" and "ssim" for CSIM parameter extraction. In these cases, the files are used in **RAM:**.

filename	program	streams these control files	output filename
startup.TEXT	measure	prbsetup.TEXT	foo
nmosdemo.TEXT	measure	mvright.TEXT mvdown.TEXT	demout.TEXT
cchains.TEXT	measure	cchain.TEXT	cchaino.TEXT
meandors.TEXT	measure	meandor.TEXT	meandoro.TEXT
ivd2910ds.TEXT	measure	mvright.TEXT mvdown.TEXT dnmosivds.TEXT	ivd2910o.TEXT
ivg2910ds.TEXT	measure	dnmosivgs.TEXT	ivg2910o.TEXT
sim2910ds.TEXT	measure cmeas ssim	nssimsmu4.TEXT foo1 reduc1.TEXT	foo1 reduc1.TEXT csim2910d.TEXT
ivd2410cs.TEXT	measure	cpmosivds.TEXT	ivd2410co.TEXT
ivg2410cs.TEXT	measure	cpmosivgs.TEXT	ivg2410co.TEXT
sim2410cs.TEXT	measure cmeas ssim	pssimsmu3.TEXT foo2 reduc2.TEXT	foo2 reduc2.TEXT csim2410c.TEXT

****** GRAPHICS PLOT ******

PACTIVE CROSS BRIDGE



	GRAD	1/GRAD	Xintercept	Yintercept
LINE1	4.33E-03	231E+00	-40.5E-03	175E-06
LINE2				

VX (V) = (VSENS3-VSENS2)

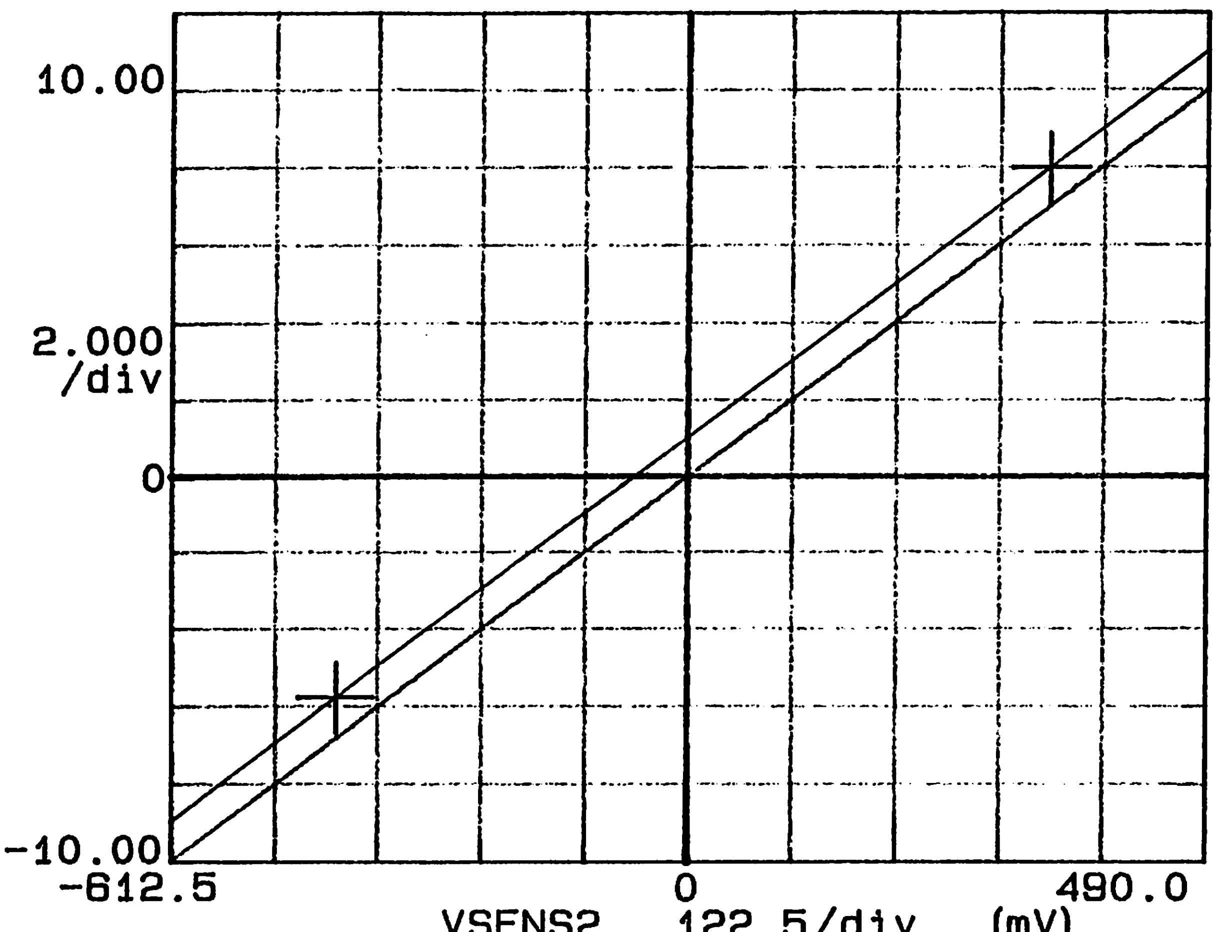
Variable1:
IFORCE-Ch4
Linear sweep
Start -10.00mA
Stop 10.00mA
Step 100.0uA

Constants:
ISENS2-Ch2 .000 A
ISENS3-Ch3 .000 A
VGND -Vs2 .0000V

****** GRAPHICS PLOT ******

NACTIVE CROSS BRIDGE

IFORCE (mA) CURSOR(- .4170V , -5.776mA ,)



Variable1:
IFORCE-Ch4
Linear sweep
Start -10.00mA
Stop 10.00mA
Step 100.0uA

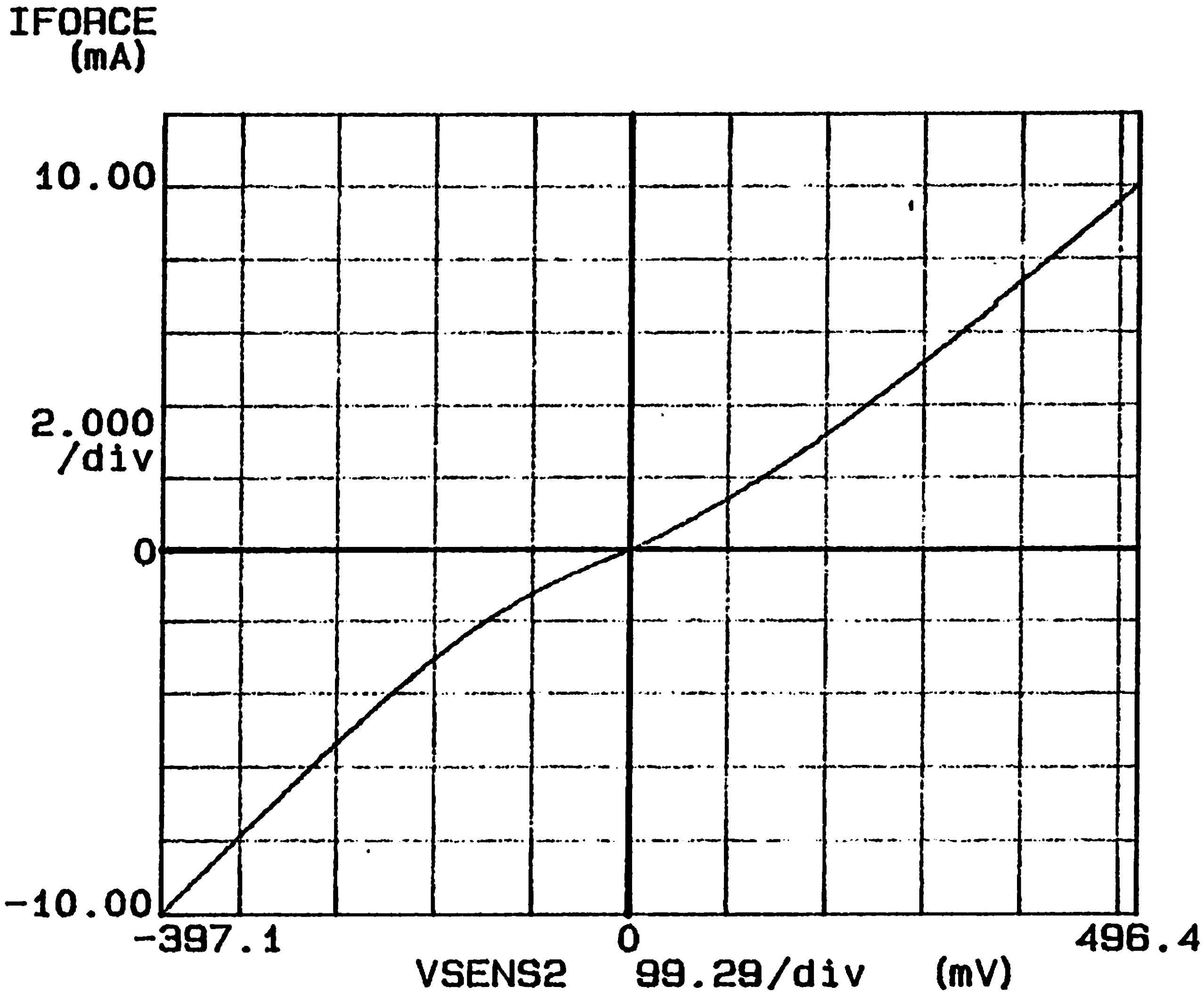
Constants:
ISENS2-Ch2 .000 A
ISENS3-Ch3 .000 A
VGND -Vs2 .0000V

	GRAD	1/GRAD	Xintercept	Yintercept
LINE1	16.3E-03	61.4E+00	-62.6E-03	1.02E-03
LINE2				

VX (V) = (VSENS3-VSENS2)

****** GRAPHICS PLOT ******

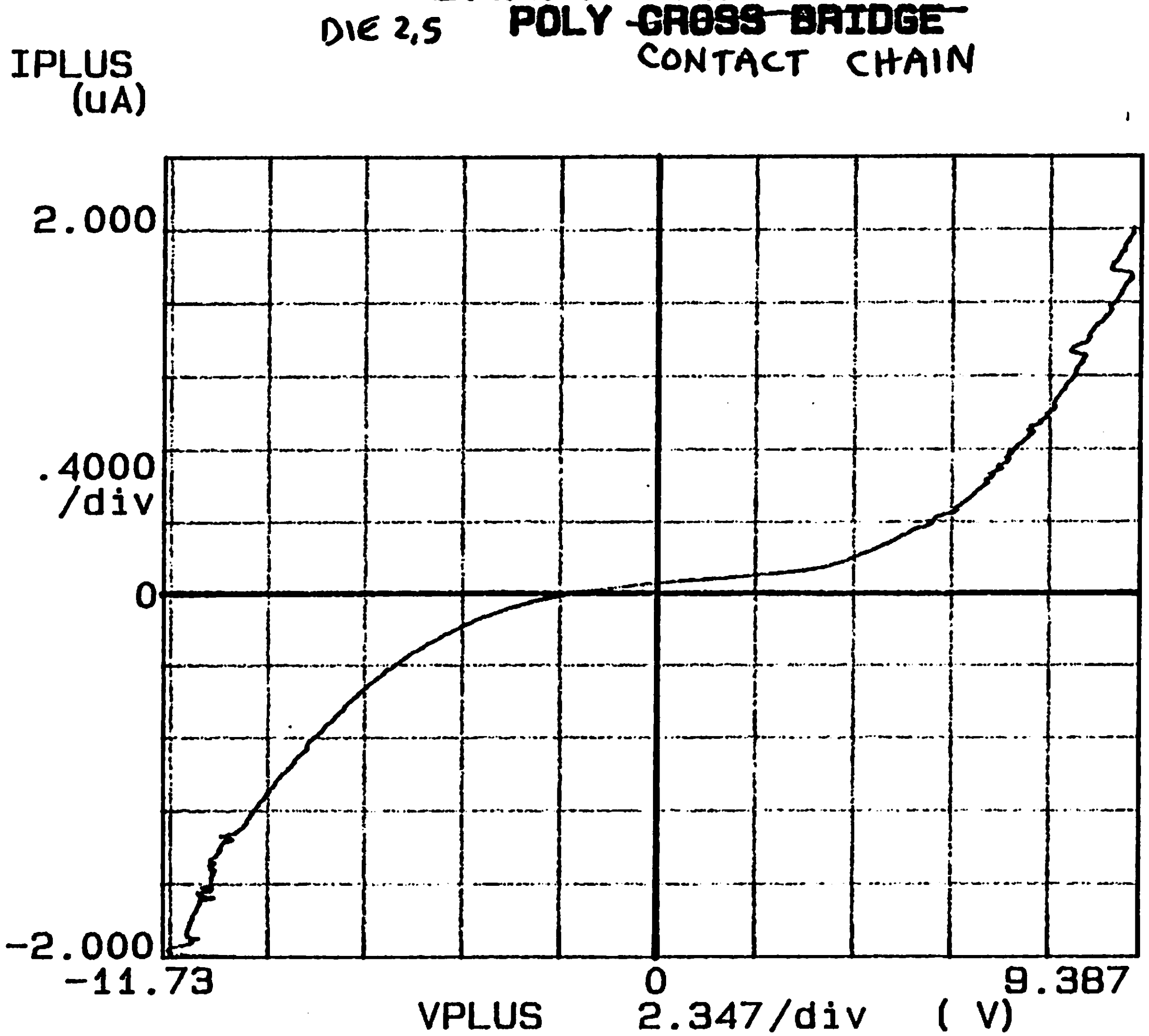
POLY CROSS BRIDGE



Variable1:
IFORCE-Ch4
Linear sweep
Start -10.00mA
Stop 10.00mA
Step 100.0uA

Constants:
ISENS2-Ch2 .000 A
ISENS3-Ch3 .000 A
VGND -Vs2 .0000V

****** GRAPHICS PLOT ******

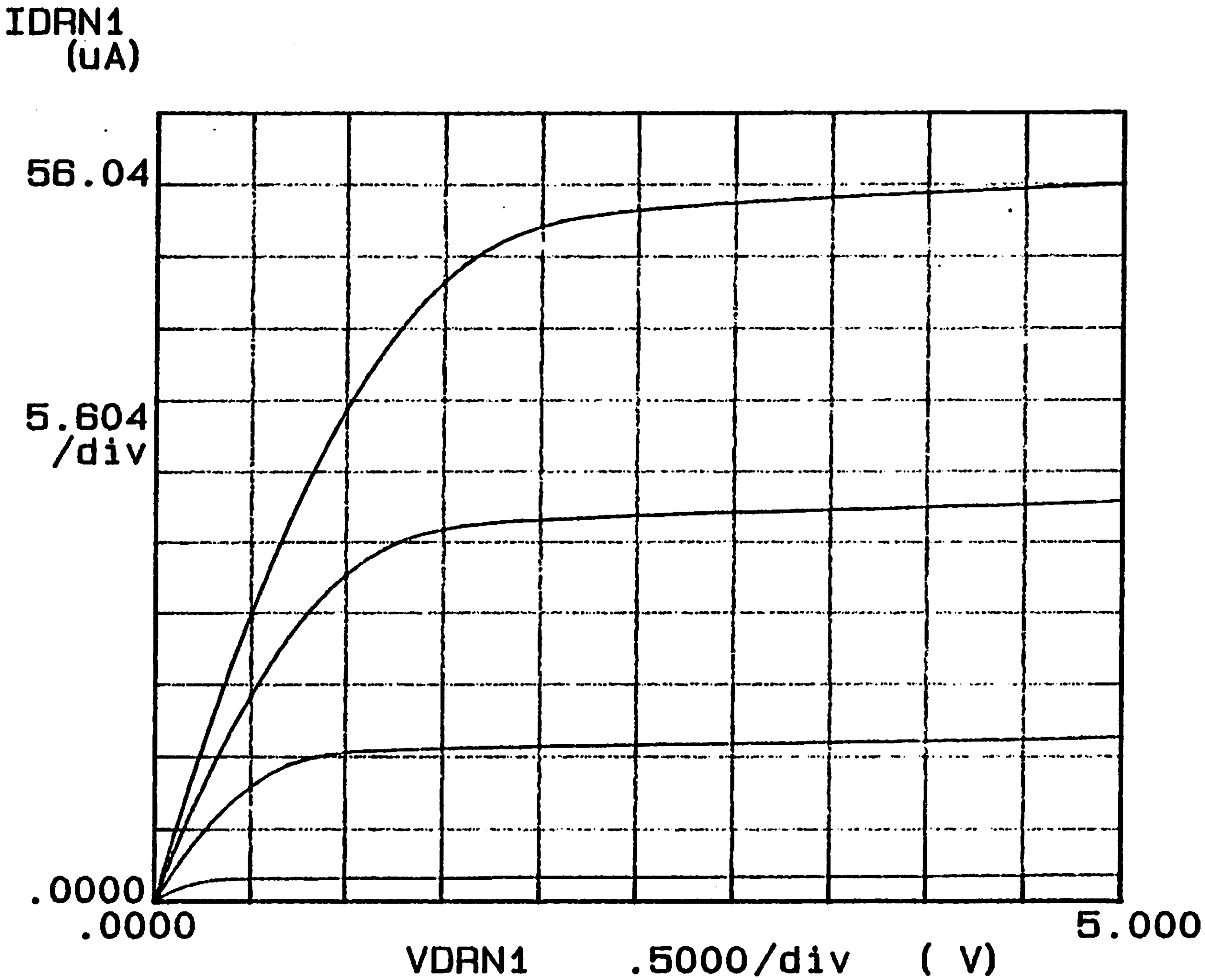


Variable1:
IPLUS -Ch1
Linear sweep
Start -2.000uA
Stop 2.000uA
Step 10.00nA

Constants:
VGND -Vs2 .0000V

****** GRAPHICS PLOT ******

DIE 2,5 W/L 0.6u/1.2u



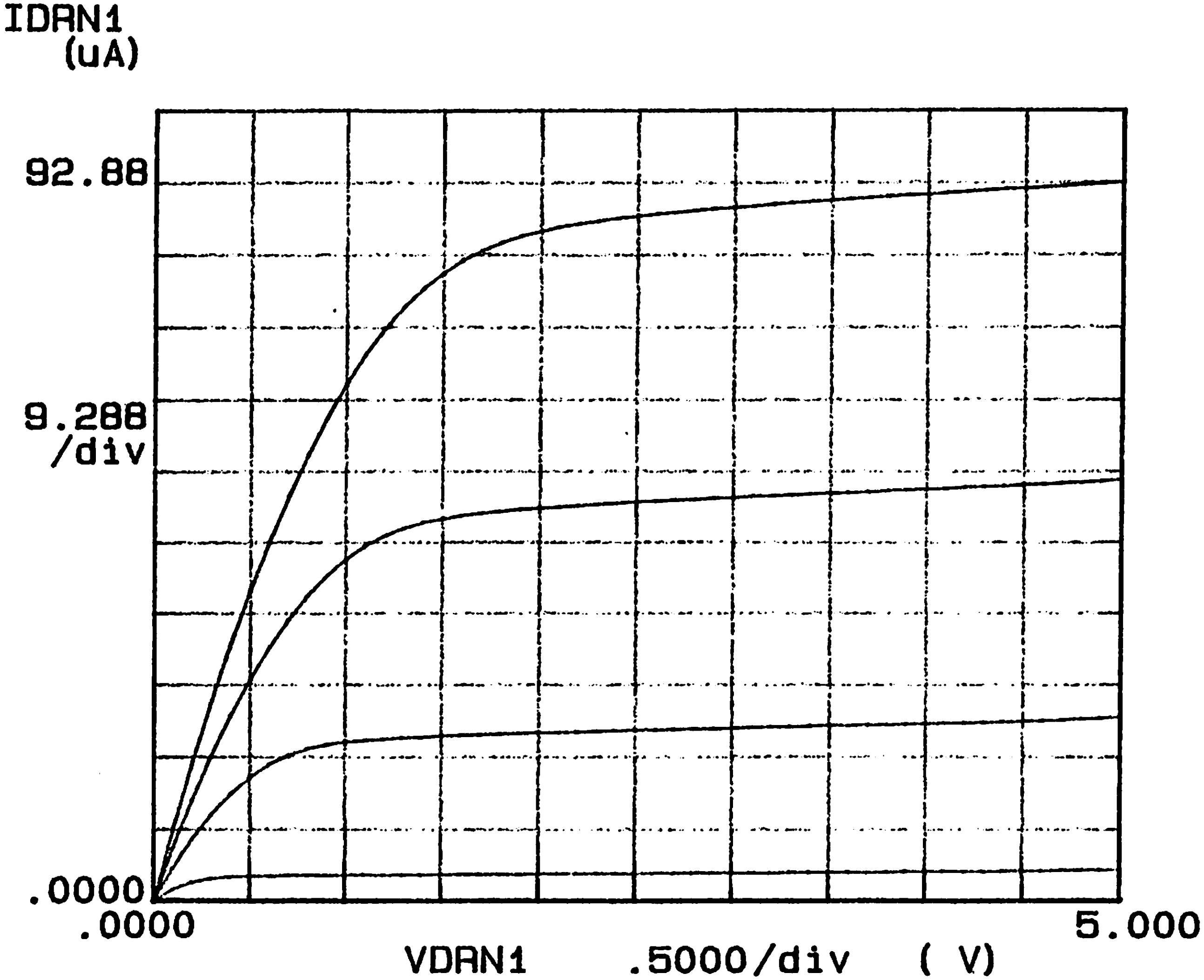
Variable1:
VDRN1 -Ch1
Linear sweep
Start .0000V
Stop 5.0000V
Step .1000V

Variable2:
VGATE -Vs1
Start .0000V
Stop 5.0000V
Step 1.0000V

Constants:
VDRN3 -Ch3 .0000V
VBODY -Vs2 .0000V

****** GRAPHICS PLOT ******

DIE 2,5 0.8/1.2u



Variable1:
VDRN1 -Ch1
Linear sweep

Start	.0000V
Stop	5.0000V
Step	.1000V

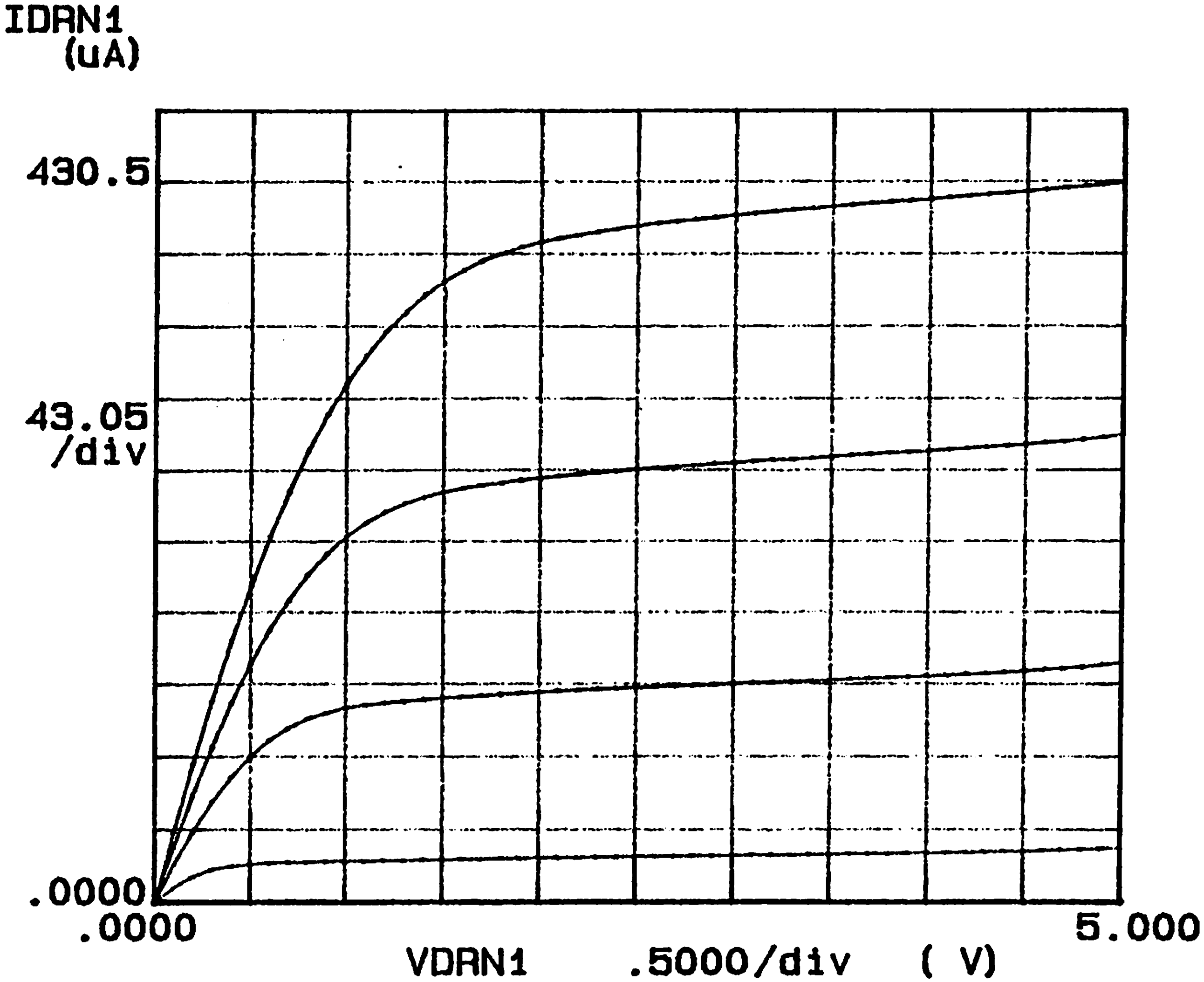
Variable2:
VGATE -Vs1

Start	.0000V
Stop	5.0000V
Step	1.0000V

Constants:
VBODY -Vs2 .0000V

****** GRAPHICS PLOT ******

DIE 2,5 2.4/0.6u



Variable1:
VDRN1 -Ch1
Linear sweep

Start	.0000V
Stop	5.0000V
Step	.1000V

Variable2:
VGATE -Vs1

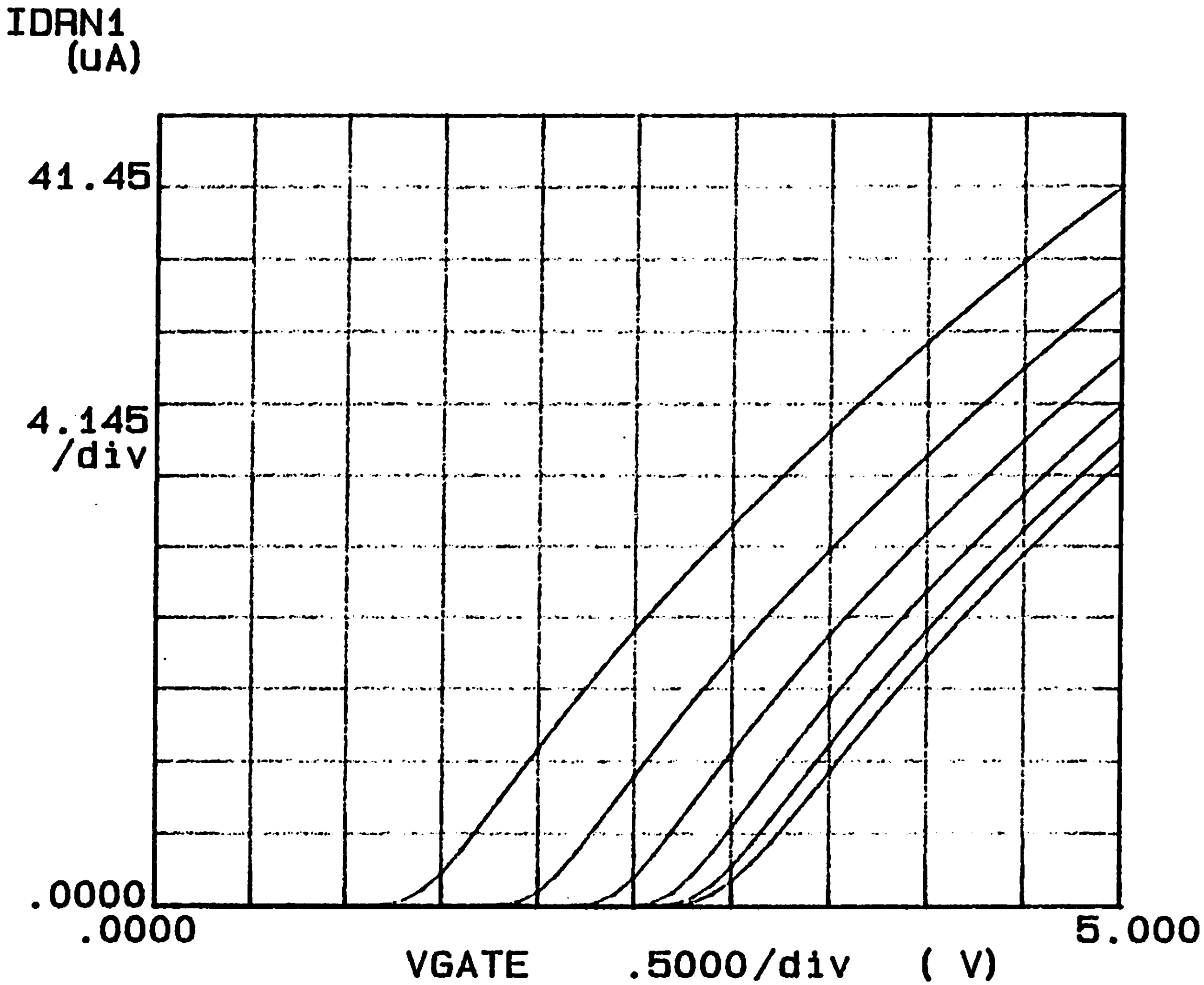
Start	.0000V
Stop	5.0000V
Step	1.0000V

Constants:

VBODY -Vs2	.0000V

****** GRAPHICS PLOT ******

DIE 2,5 2.4/0.6u



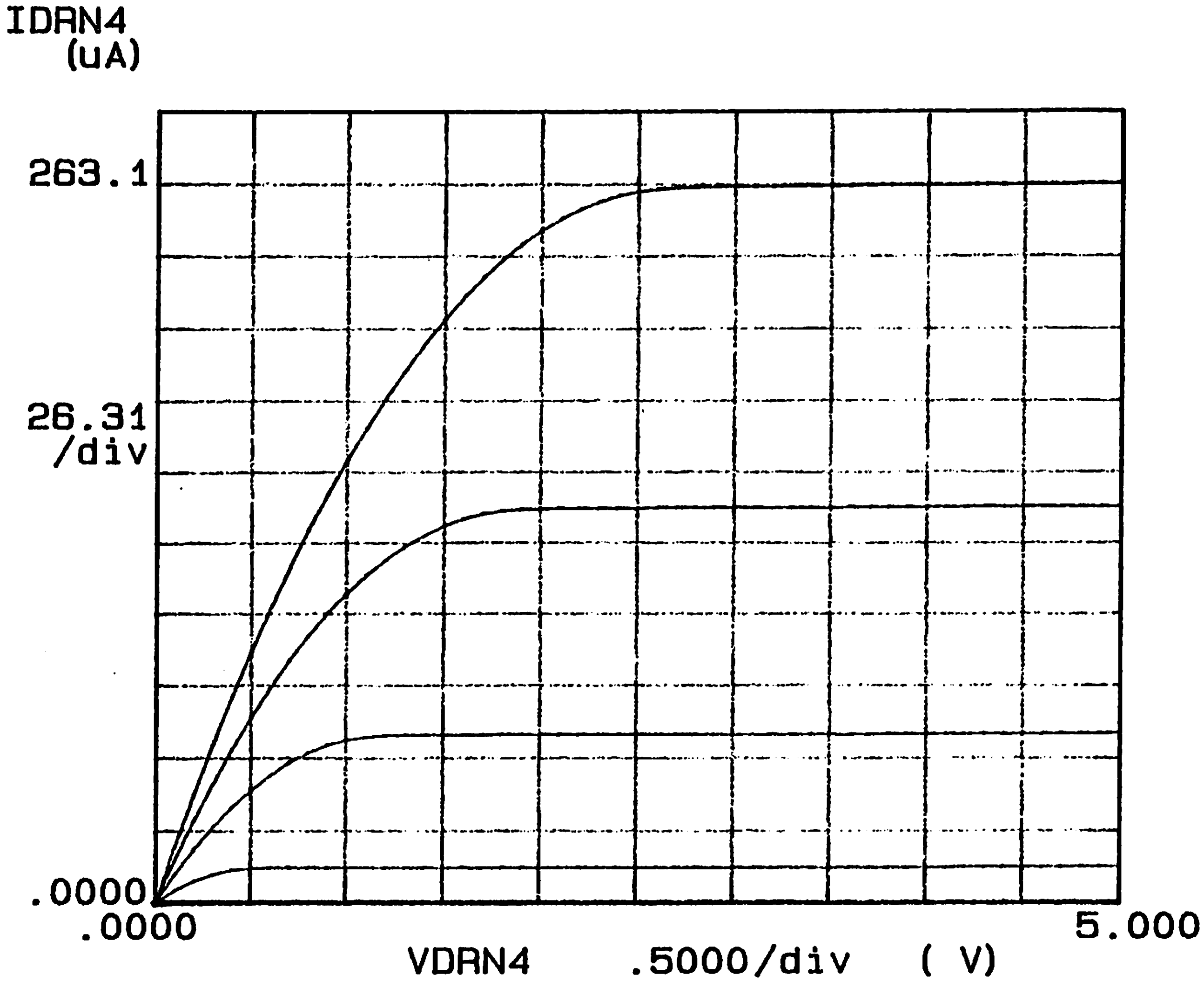
Variable1:
VGATE -Vs1
Linear sweep
Start .0000V
Stop 5.0000V
Step .1000V

Variable2:
VBODY -Vs2
Start -5.0000V
Stop .0000V
Step 1.0000V

Constants:
VDRN1 -Ch1 .1000V

****** GRAPHICS PLOT ******

DIE 2, 5 W/L 38.4/38.4



Variable1:
VDRN4 -Ch4
Linear sweep

Start	.0000V
Stop	5.0000V
Step	.1000V

Variable2:
VGATE -Vs1

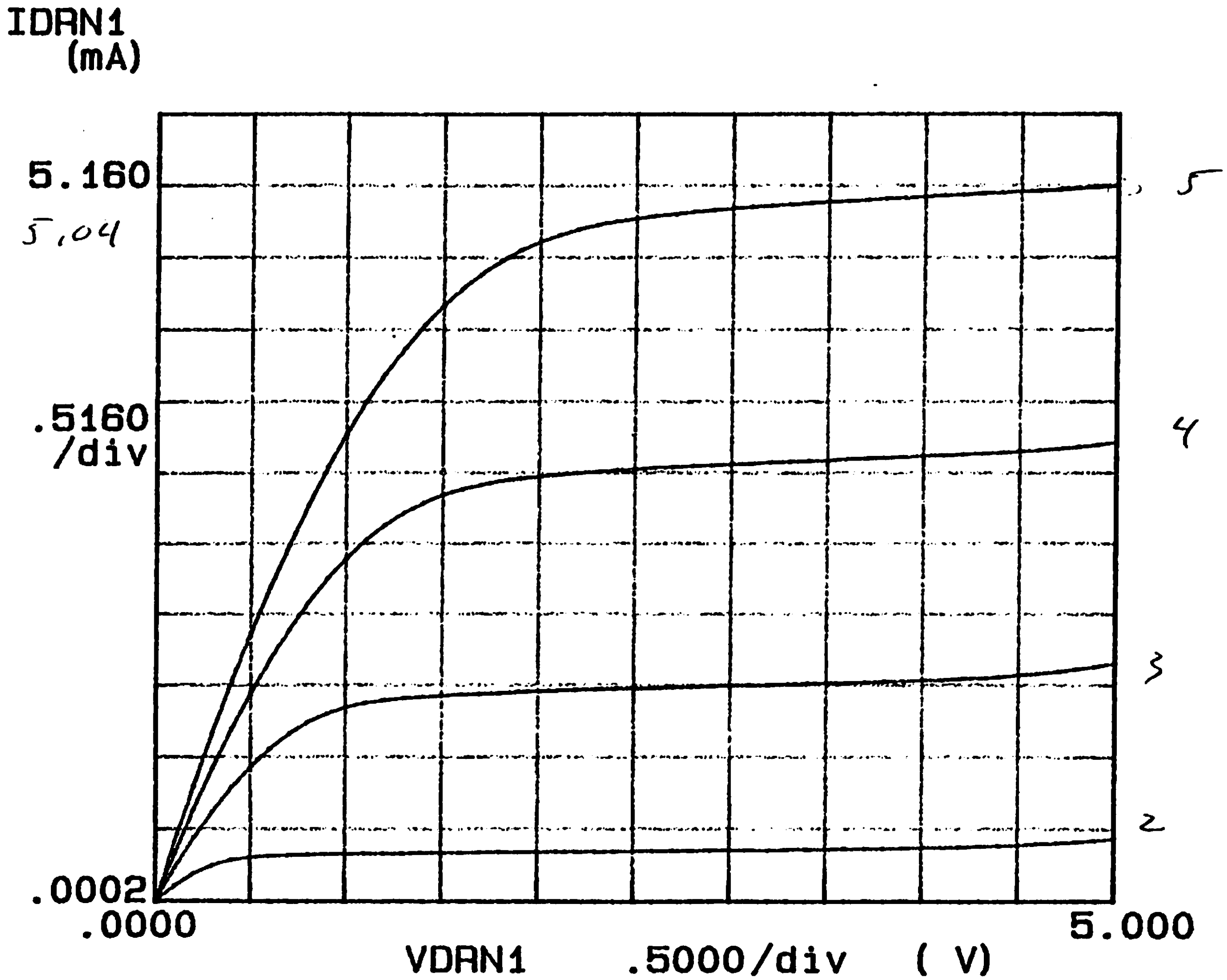
Start	.0000V
Stop	5.0000V
Step	1.0000V

Constants:

VBODY -Vs2	.0000V

****** GRAPHICS PLOT ******

DIE 2,5 38.4/1.2u



Variable1:
VDRN1 -Ch1
Linear sweep
Start .0000V
Stop 5.0000V
Step .1000V

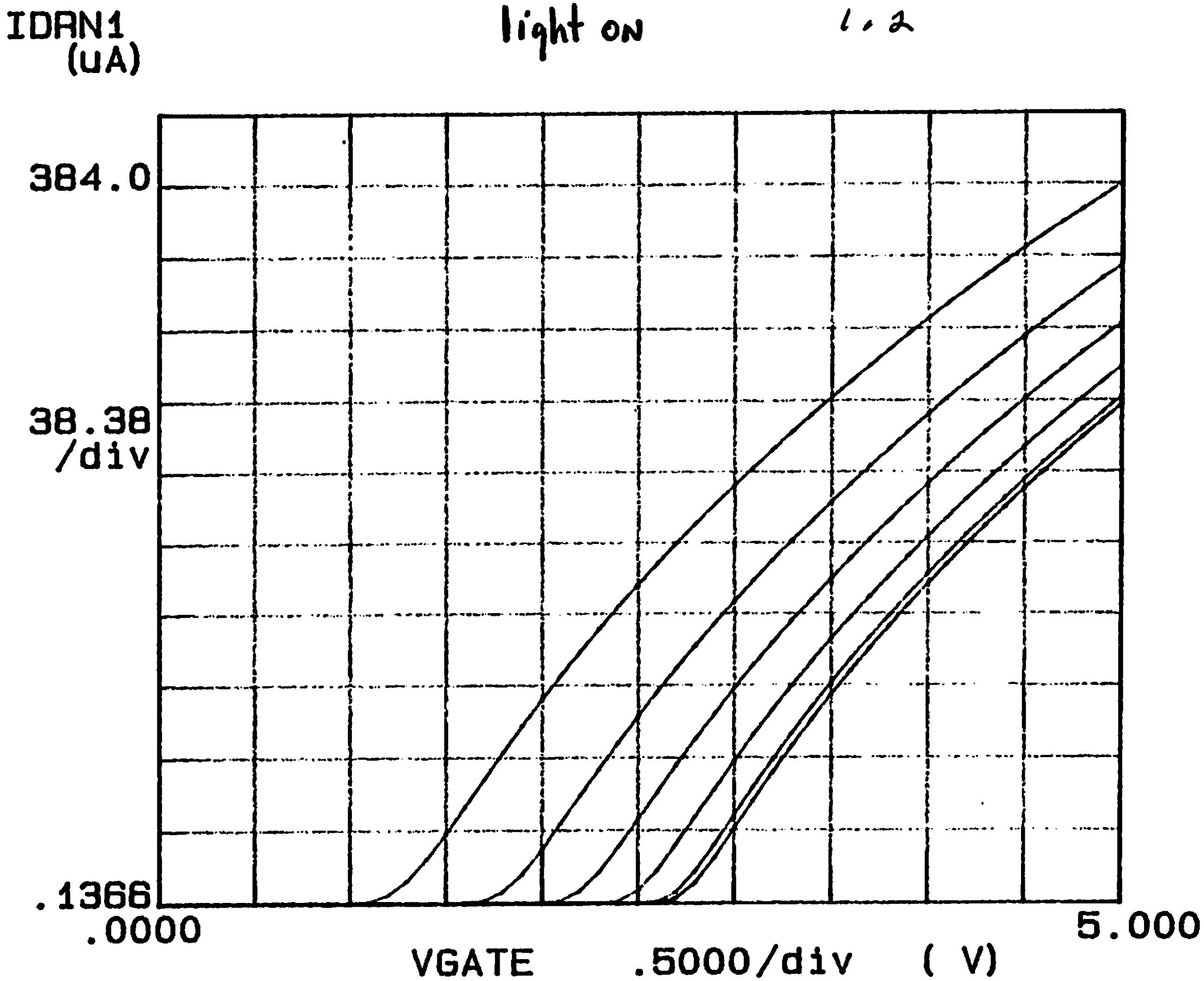
Variable2:
VGATE -Vs1
Start .0000V
Stop 5.0000V
Step 1.0000V

Constants:
VBODY -Vs2 .0000V

******** GRAPHICS PLOT ********

DIE 2, 5 38.4/~~38.4~~u 1.2

light ON



Variable1:
VGATE -Vs1
Linear sweep
Start .0000V
Stop 5.0000V
Step .1000V

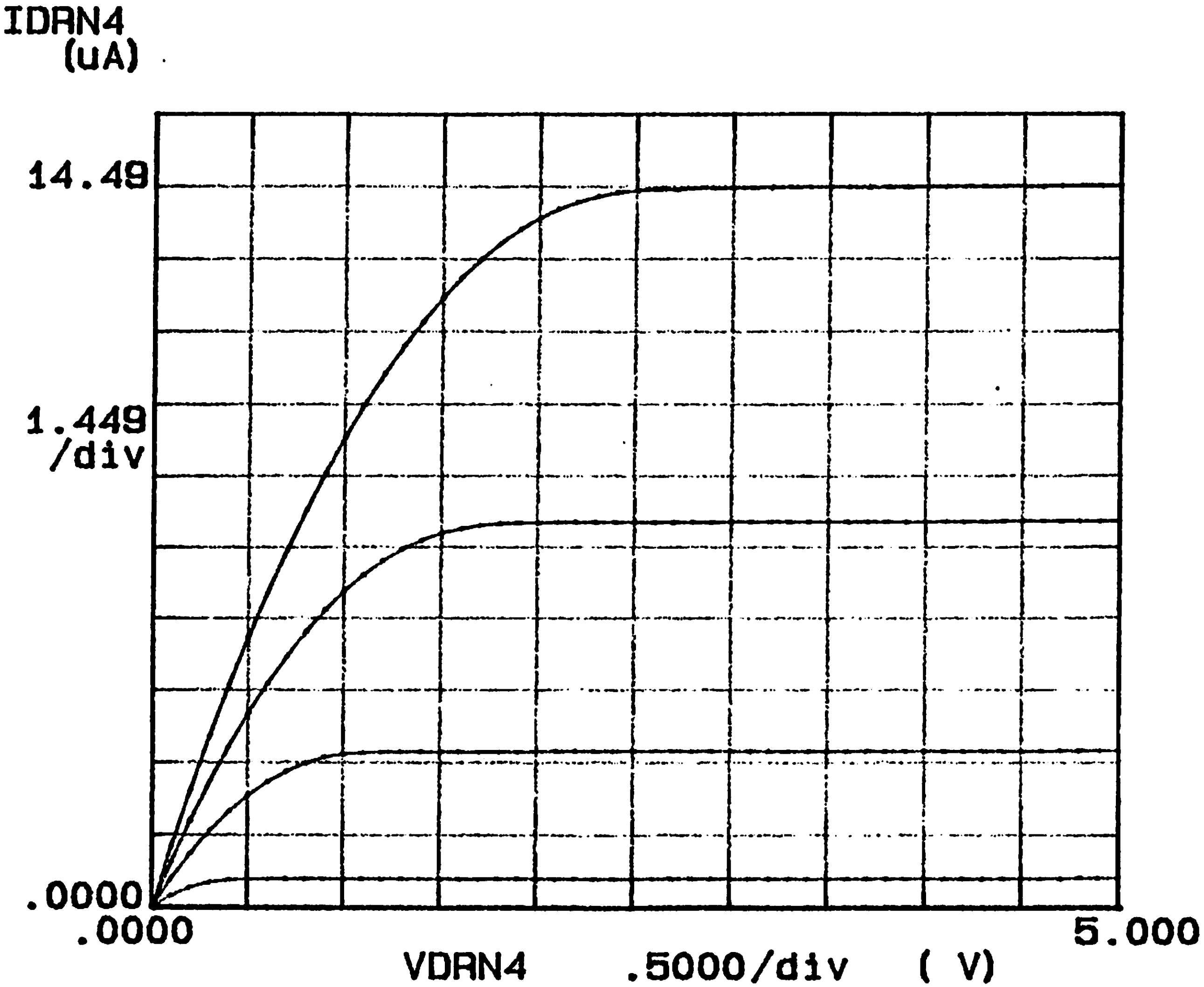
Variable2:
VBODY -Vs2
Start -5.0000V
Stop .0000V
Step 1.0000V

Constants:
VDRN1 -Ch1 .1000V

with light

****** GRAPHICS PLOT ******

DIE 2,5 2.4/38.4u



Variable1:
VDRN4 -Ch4
Linear sweep

Start	.0000V
Stop	5.0000V
Step	.1000V

Variable2:
VGATE -Vs1

Start	.0000V
Stop	5.0000V
Step	1.0000V

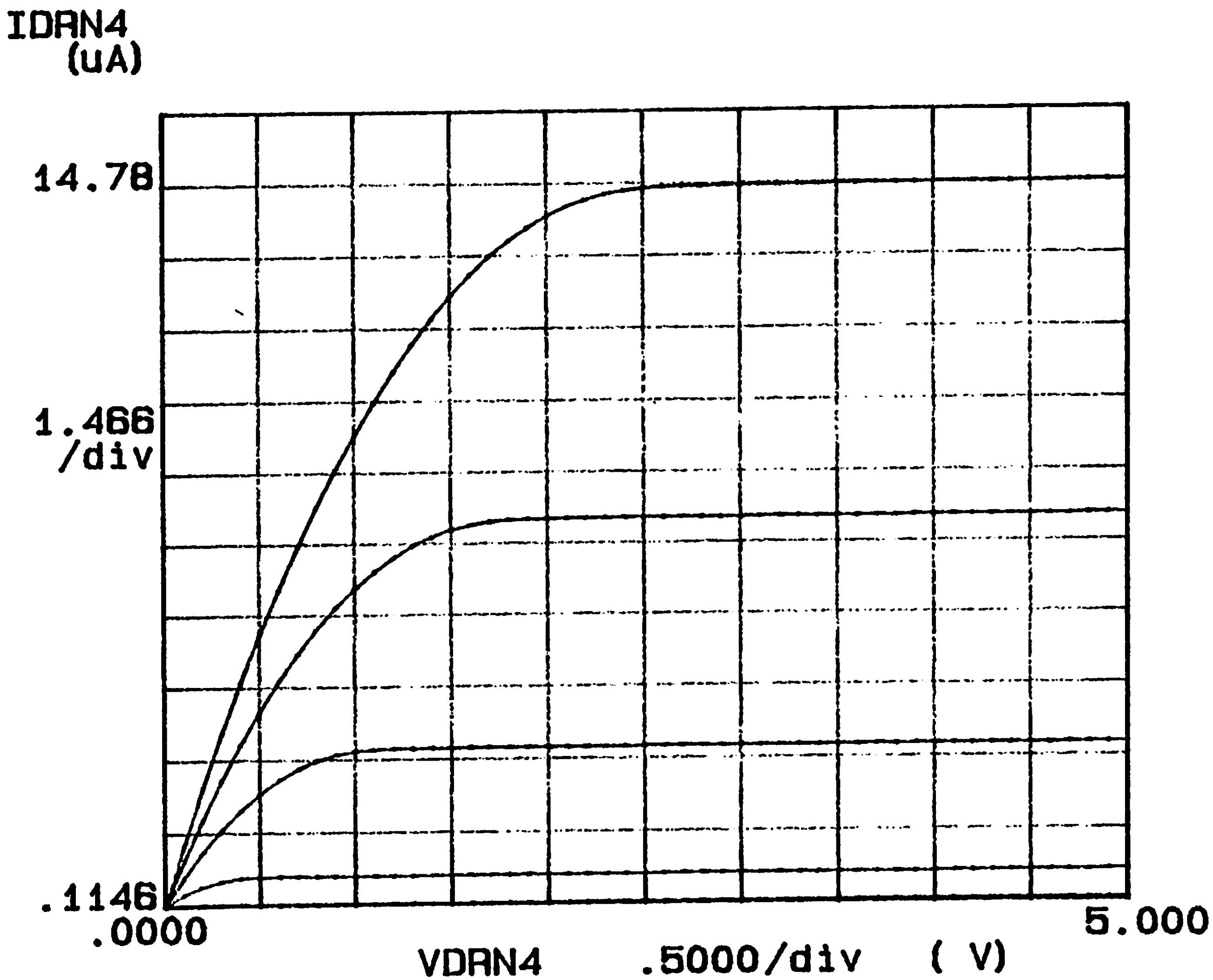
Constants:

VBODY -Vs2	.0000V

with Light On

****** GRAPHICS PLOT ******

DIE 2,5 2.4/38.4u



Variable1:
VDRN4 -Ch4
Linear sweep

Start	.0000V
Stop	5.0000V
Step	.1000V

Variable2:
VGATE -Vs1

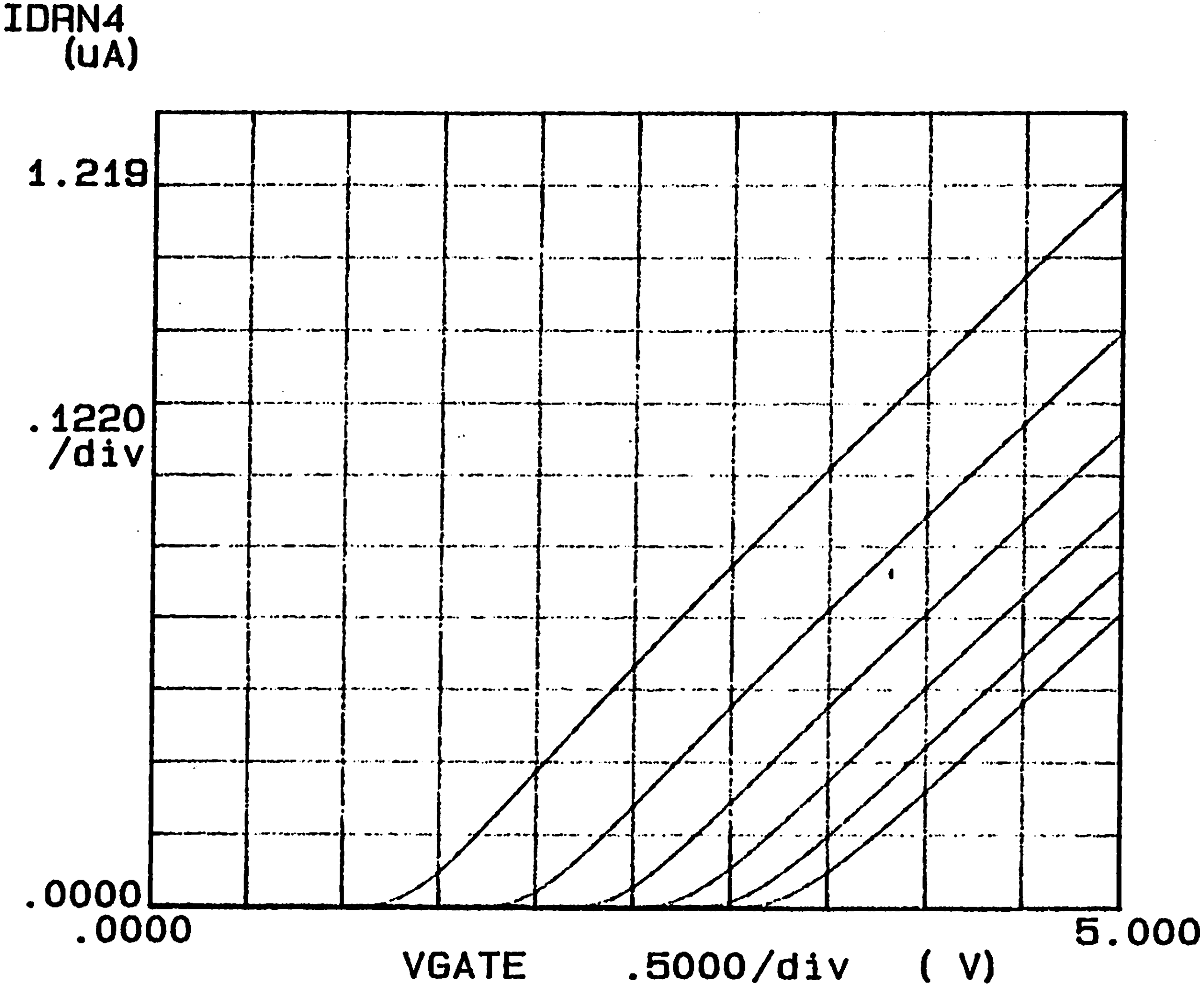
Start	.0000V
Stop	5.0000V
Step	1.0000V

Constants:

VBODY -Vs2	.0000V

****** GRAPHICS PLOT ******

DIE 2,5 2.4/38.4u



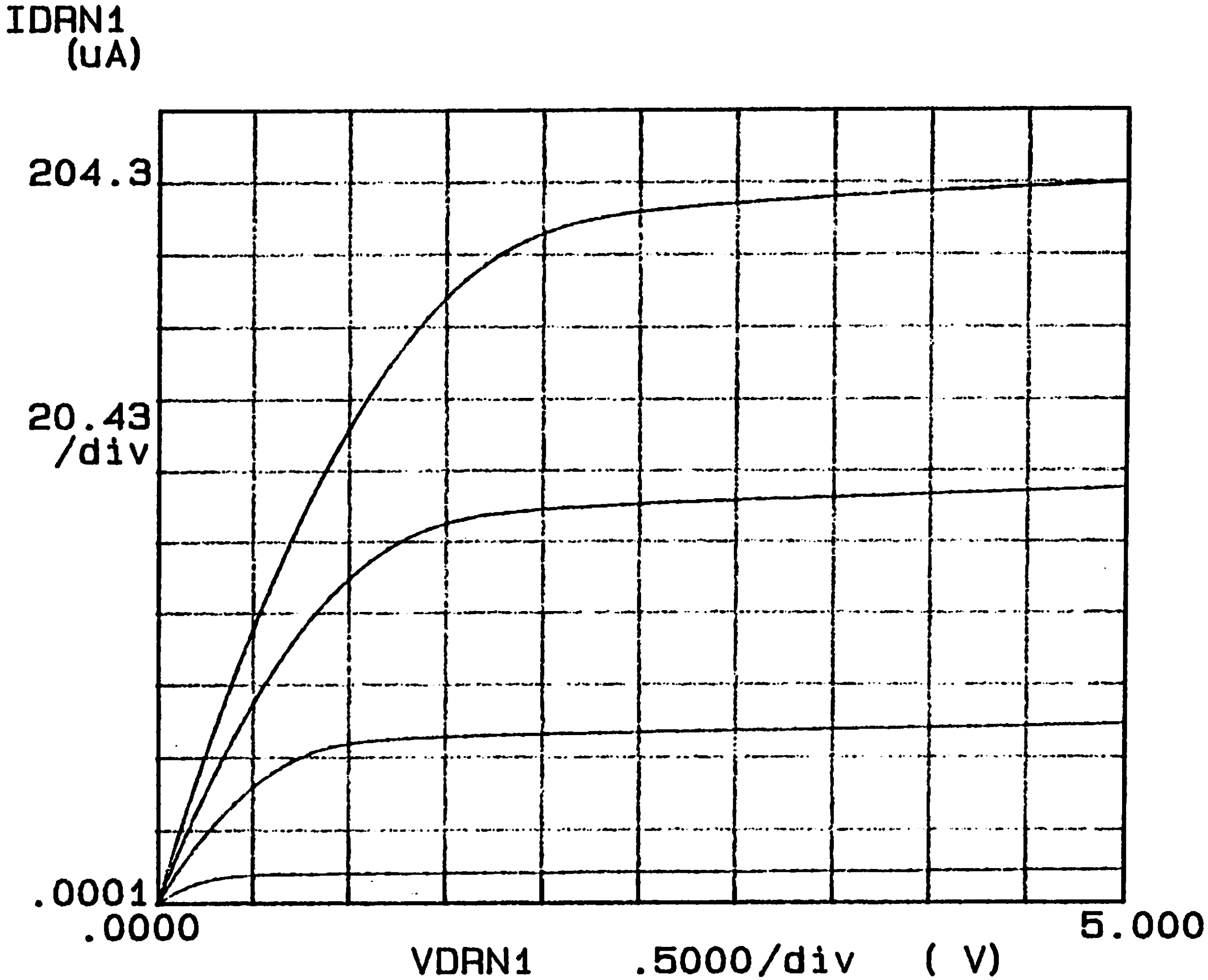
Variable1:
VGATE -Vs1
Linear sweep
Start .0000V
Stop 5.0000V
Step .1000V

Variable2:
VBODY -Vs2
Start -5.0000V
Stop .0000V
Step 1.0000V

Constants:
VDRN4 -Ch4 .1000V

****** GRAPHICS PLOT ******

DIE 2,5 W/L 2.4/2.4



Variable1:
VDRN1 -Ch1
Linear sweep
Start .0000V
Stop 5.0000V
Step .1000V

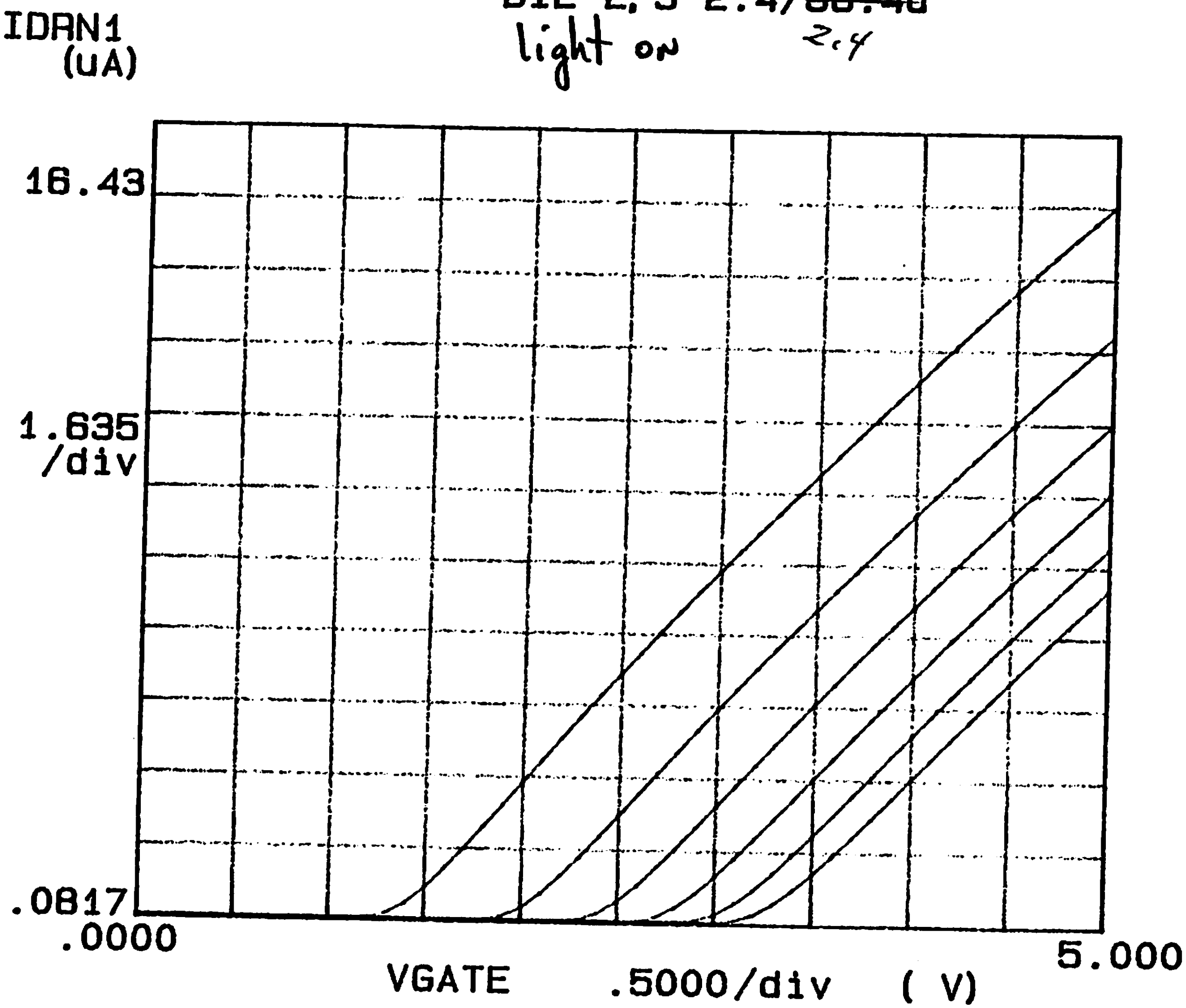
Variable2:
VGATE -Vs1
Start .0000V
Stop 5.0000V
Step 1.0000V

Constants:
VBODY -Vs2 .0000V

****** GRAPHICS PLOT ******

DIE 2, 5 2.4/~~38.4u~~ 2.4

light on



Variable1:
VGATE -Vs1
Linear sweep

Start	.0000V
Stop	5.0000V
Step	.1000V

Variable2:
VBODY -Vs2

Start	-5.0000V
Stop	.0000V
Step	1.0000V

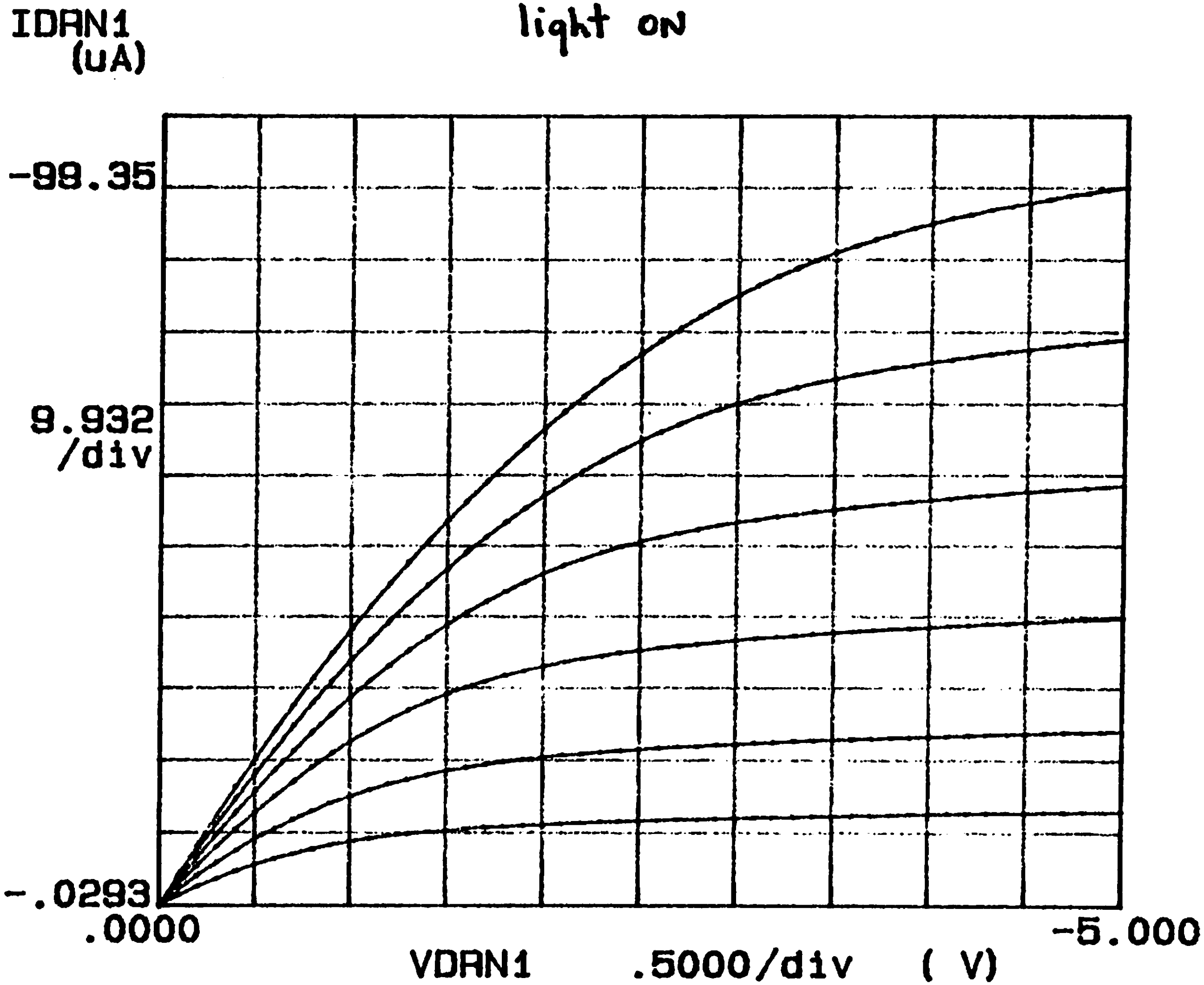
Constants:

VDRN1 -Ch1	.1000V

****** GRAPHICS PLOT ******

DIE 2.5 0.6/1.2u

light ON



Variable1:
VDRN1 -Ch1
Linear sweep

Start	.0000V
Stop	-5.0000V
Step	- .1000V

Variable2:
VGATE -Vs1

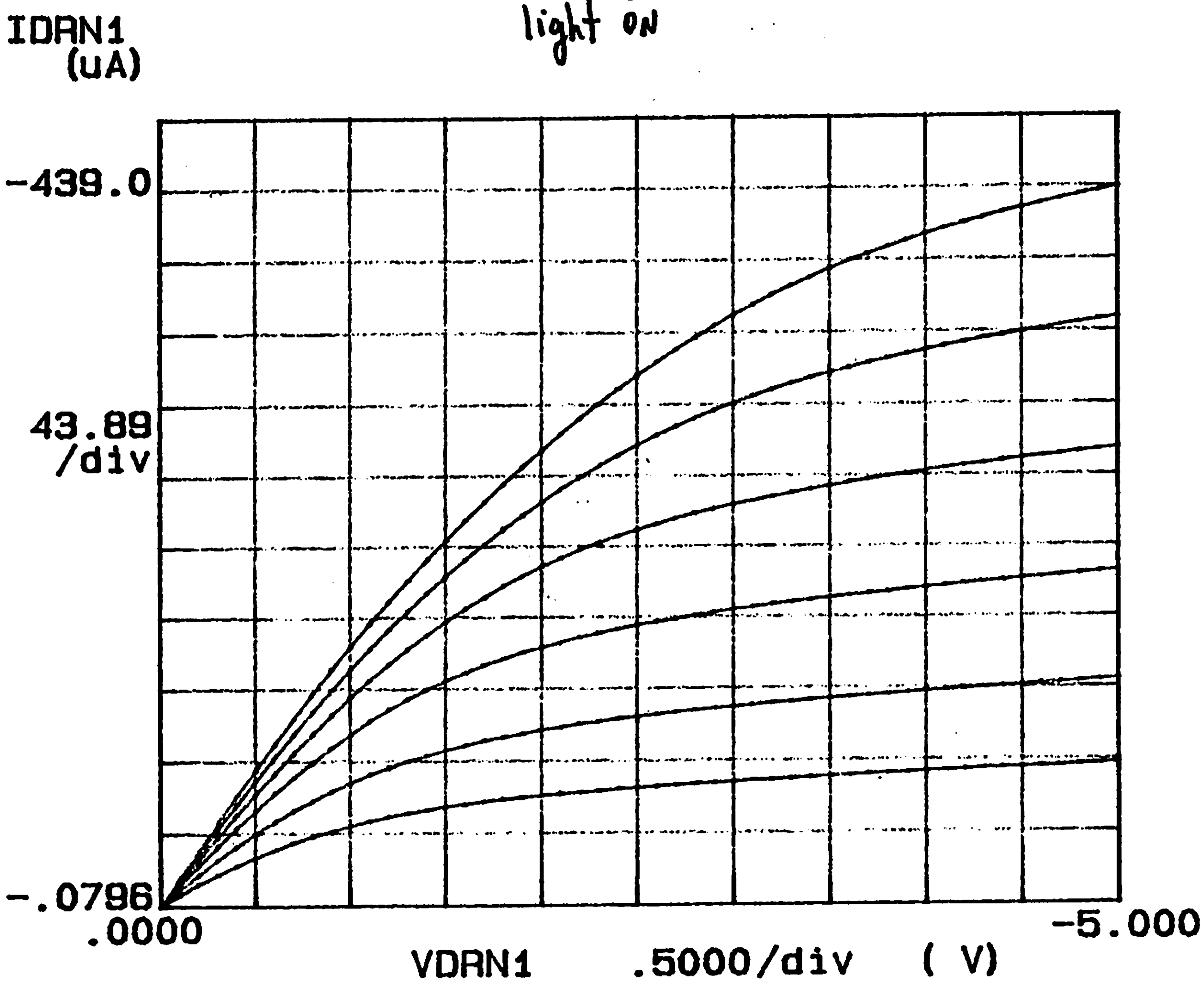
Start	.0000V
Stop	-5.0000V
Step	-1.0000V

Constants:
VBODY -Vs2 .0000V

****** GRAPHICS PLOT ******

DIE 2,5 2.4/0.6u

light ON



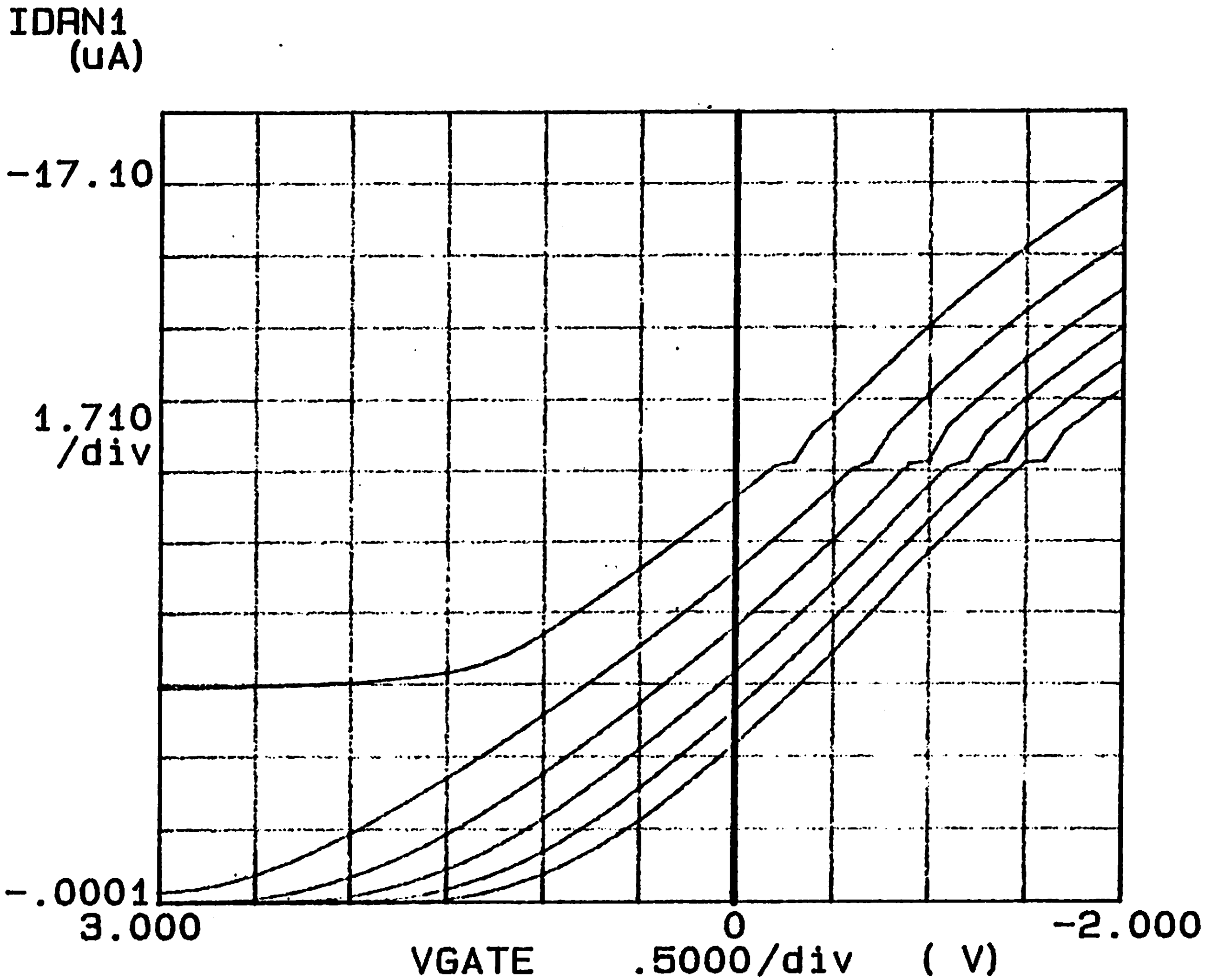
Variable1:
VDRN1 -Ch1
Linear sweep
Start .0000V
Stop -5.0000V
Step - .1000V

Variable2:
VGATE -Vs1
Start .0000V
Stop -5.0000V
Step -1.0000V

Constants:
VBODY -Vs2 .0000V

****** GRAPHICS PLOT ******

DIE 2,5 W/L 2.4/0.8



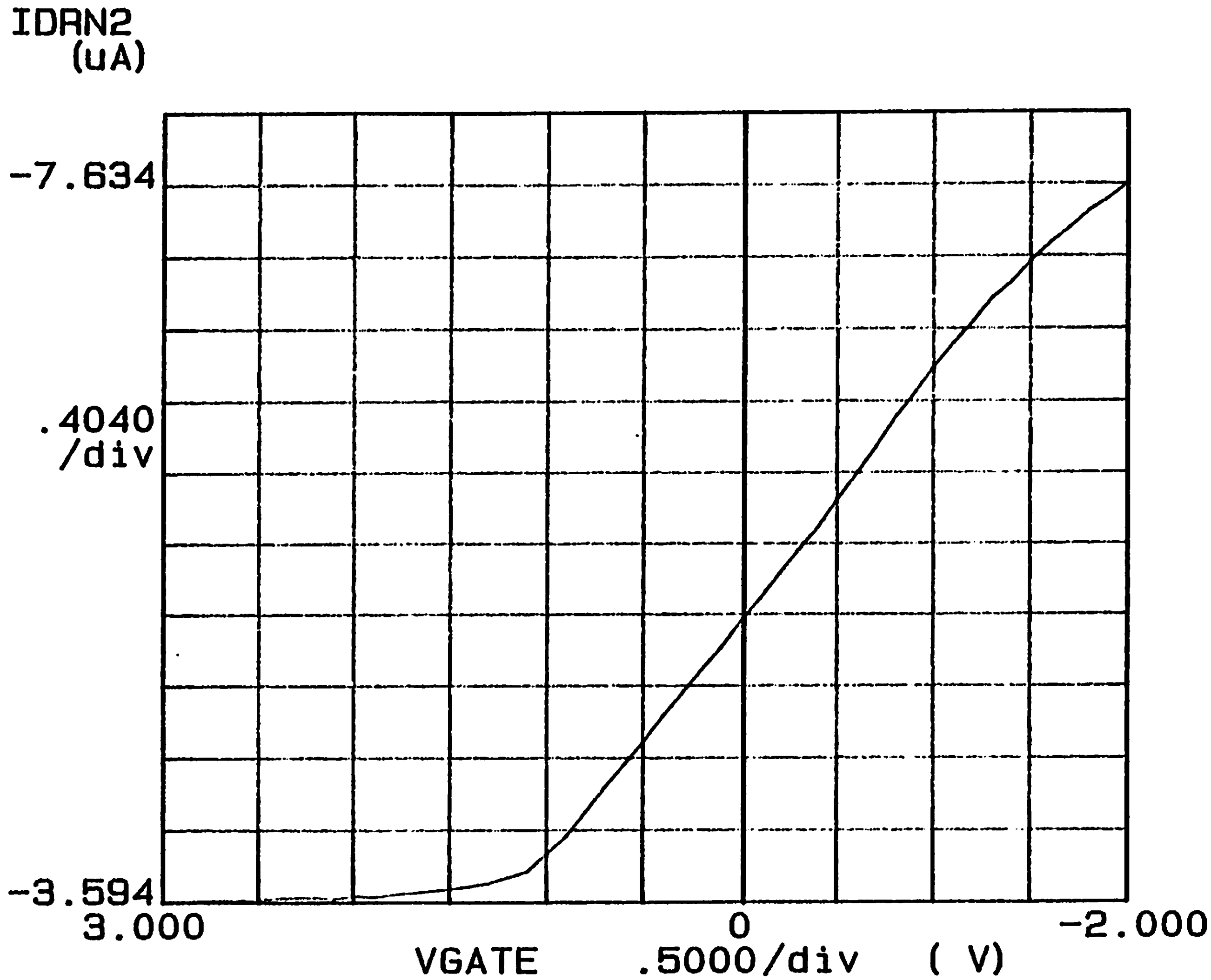
Variable1:
VGATE -Vs1
Linear sweep
Start 3.0000V
Stop -2.0000V
Step - .1000V

Variable2:
VBODY -Vs2
Start 5.0000V
Stop .0000V
Step -1.0000V

Constants:
VDRN1 -Ch1 - .1000V

****** GRAPHICS PLOT ******

DIE 3, 4 W/L 38.4u/2.4u



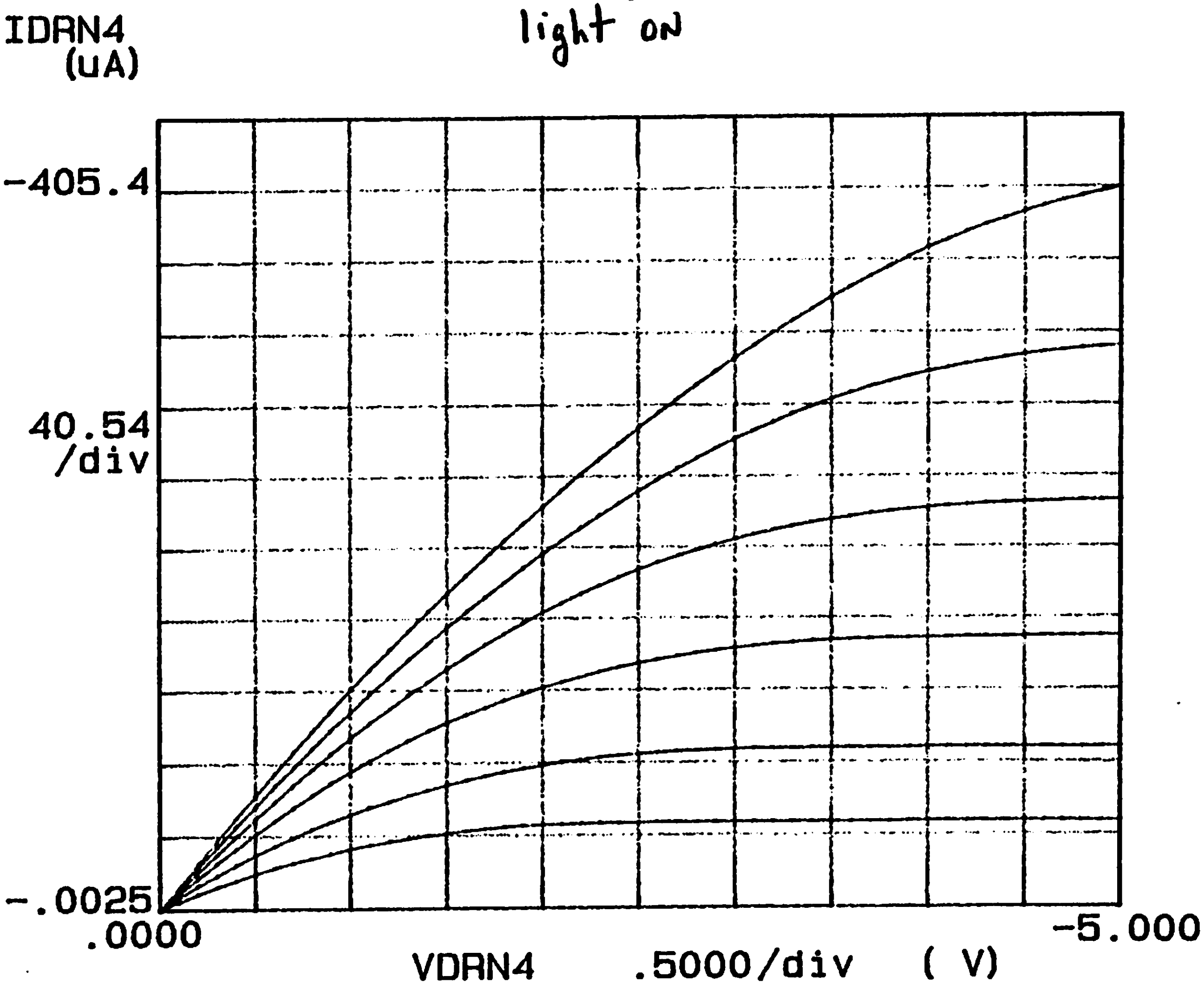
Variable1:
VGATE -Vs1
Linear sweep
Start 3.0000V
Stop -2.0000V
Step - .1000V

Constants:
VDRN2 -Ch2 - .1000V
VBODY -Vs2 .0000V

****** GRAPHICS PLOT ******

DIE 2,5 38.4/38.4u

light ON



Variable1:
VDRN4 -Ch4
Linear sweep
Start .0000V
Stop -5.0000V
Step - .1000V

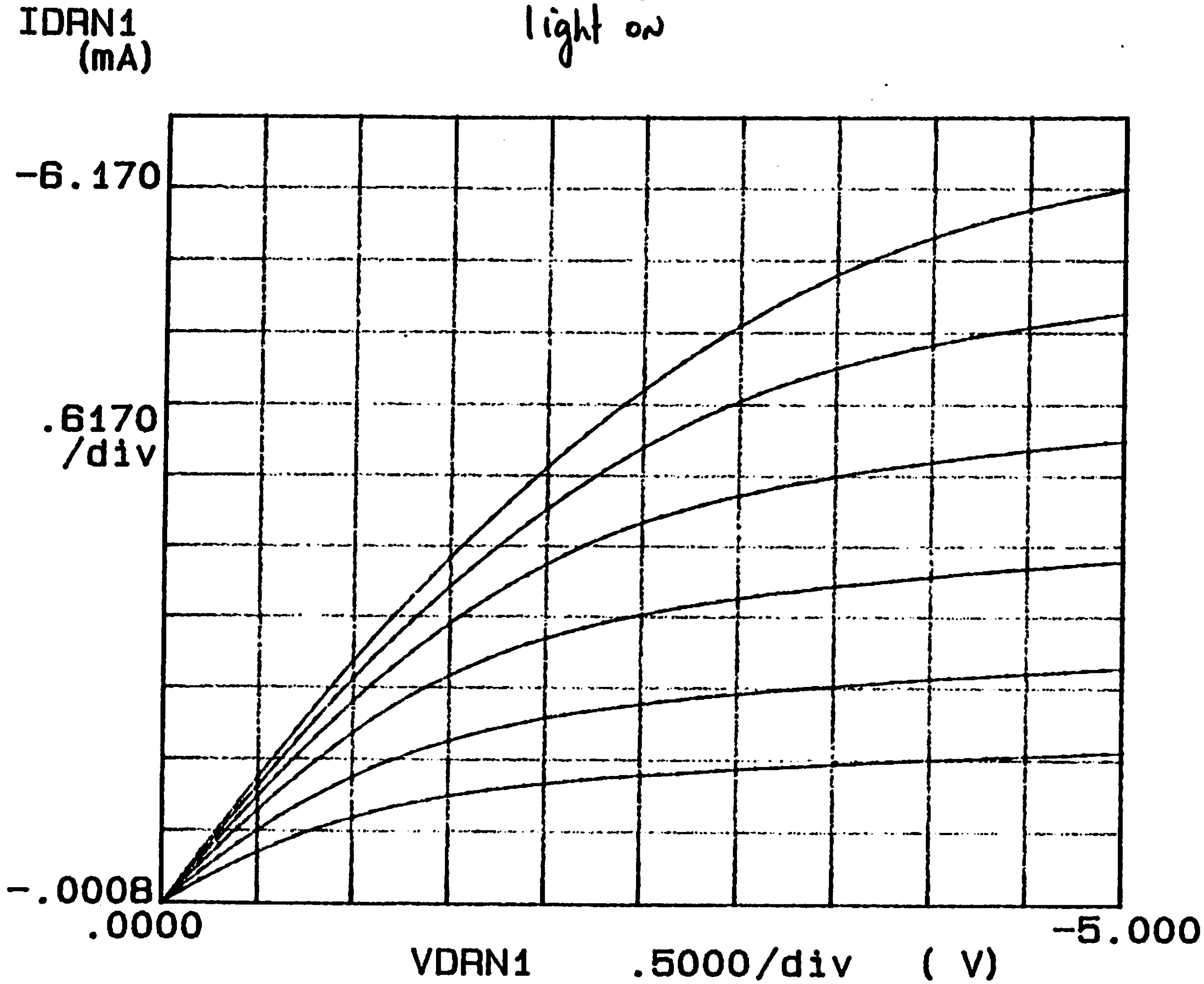
Variable2:
VGATE -Vs1
Start .0000V
Stop -5.0000V
Step -1.0000V

Constants:
VBODY -Vs2 .0000V

****** GRAPHICS PLOT ******

DIE 2,5 38.4/1.2u

light on



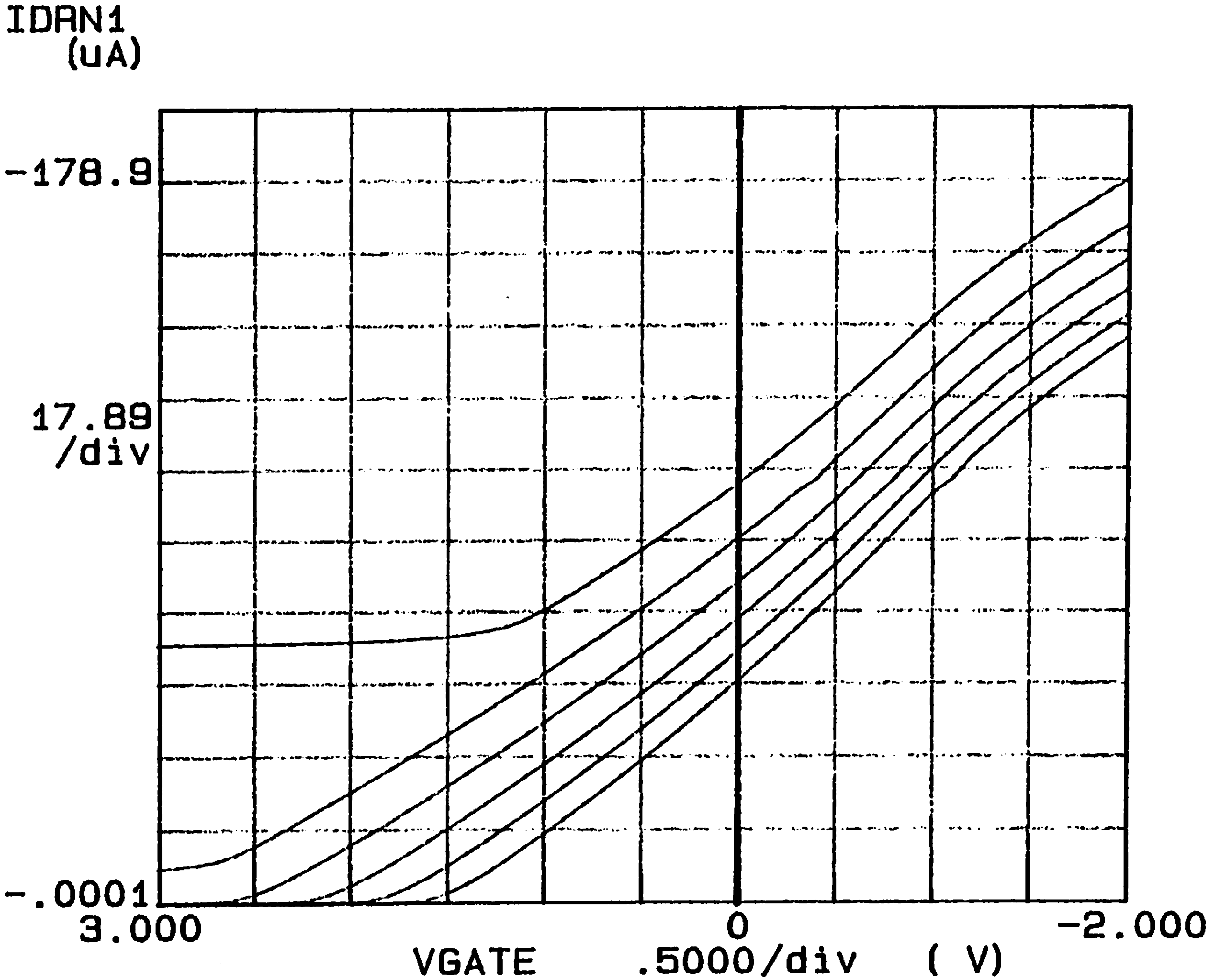
Variable1:
VDRN1 -Ch1
Linear sweep
Start .0000V
Stop -5.0000V
Step - .1000V

Variable2:
VGATE -Vs1
Start .0000V
Stop -5.0000V
Step -1.0000V

Constants:
VBODY -Vs2 .0000V

****** GRAPHICS PLOT ******

DIE 2,5 W/L 38.4/1.2



Variable1:
VGATE -Vs1
Linear sweep
Start 3.0000V
Stop -2.0000V
Step - .1000V

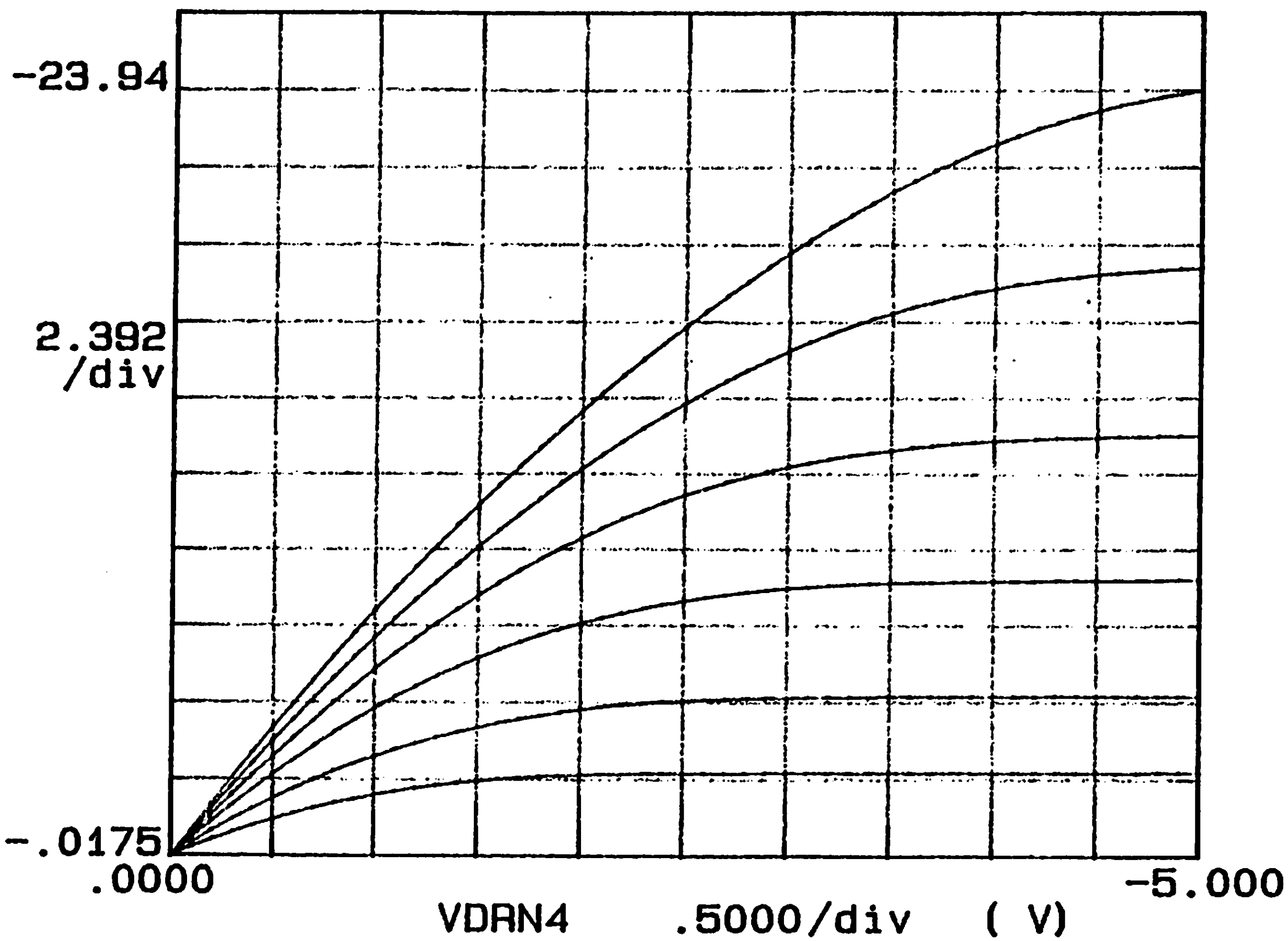
Variable2:
VBODY -Vs2
Start 5.0000V
Stop .0000V
Step -1.0000V

Constants:
VDRN1 -Ch1 - .1000V

****** GRAPHICS PLOT ******

DIE 2,5 2.4/38.4u

light on



Variable1:
VDRN4 -Ch4
Linear sweep

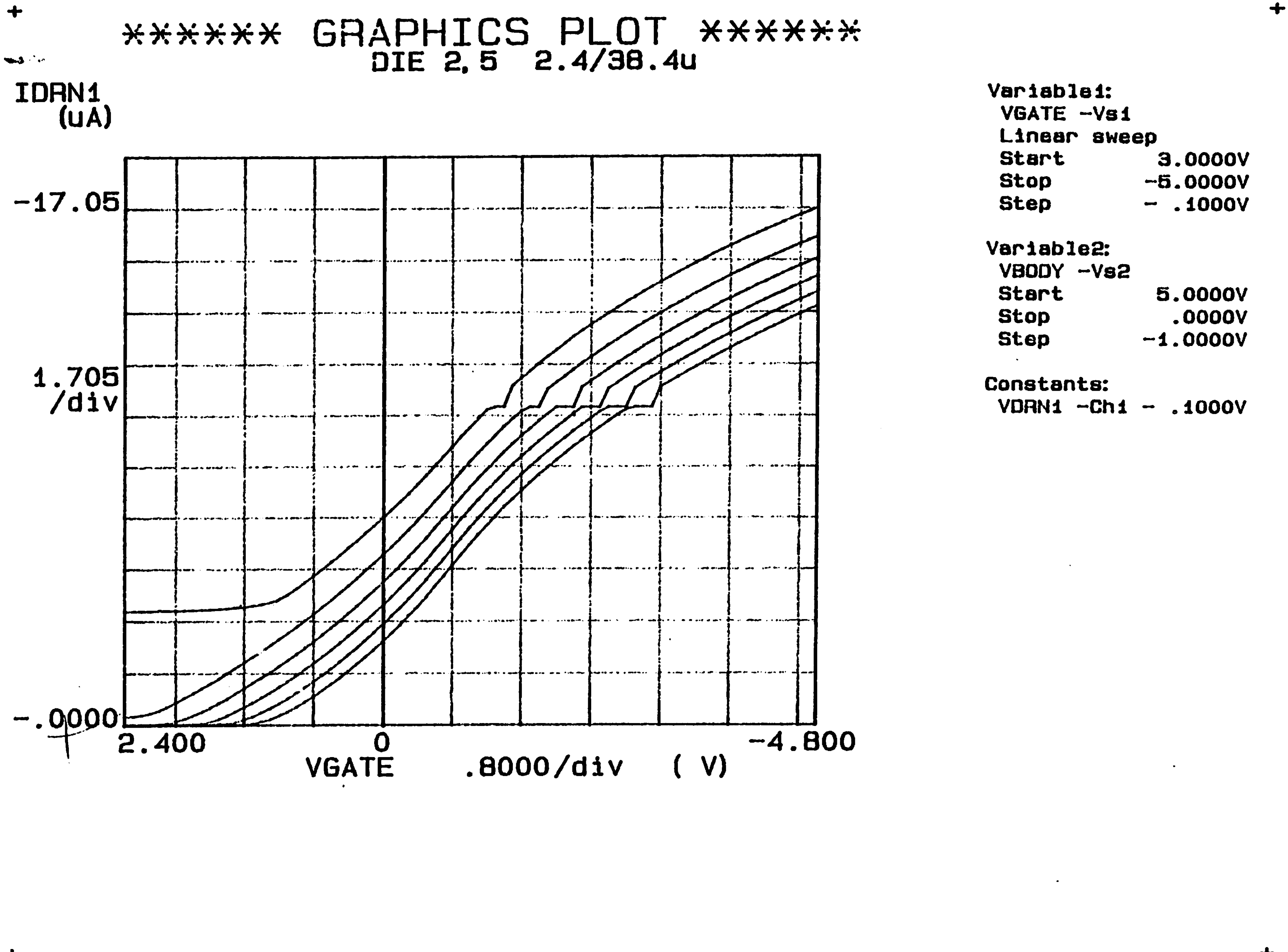
Start	.0000V
Stop	-5.0000V
Step	- .1000V

Variable2:
VGATE -Vs1

Start	.0000V
Stop	-5.0000V
Step	-1.0000V

Constants:

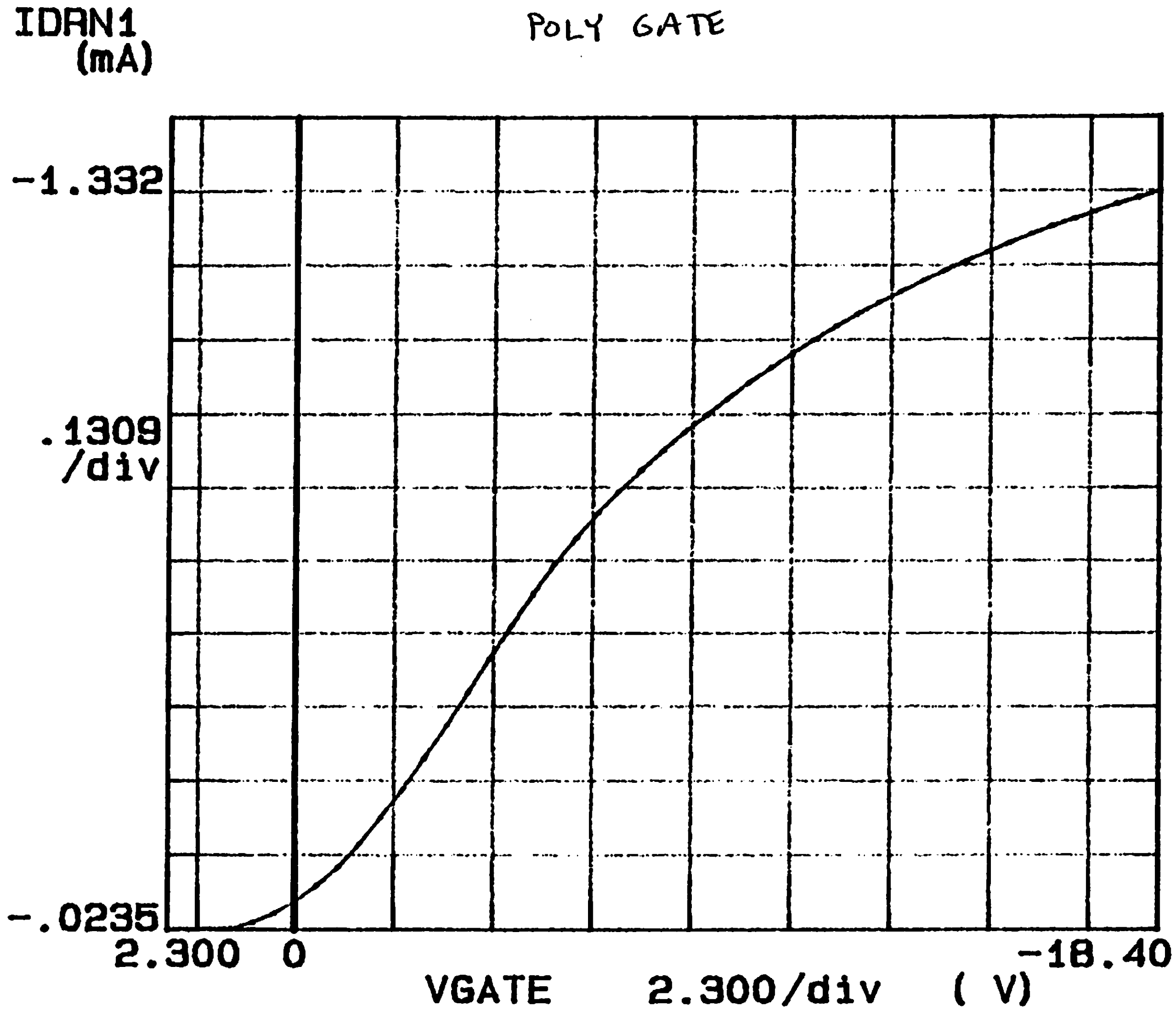
VBODY -Vs2	.0000V


****** GRAPHICS PLOT ******
DIE 2, 5 2.4/38.4u
IDRN1
(uA)
-17.05
1.705
/div
-.0000
2.400
0
-4.800
VGATE .8000/div (V)
Variable1:
VGATE -Vs1
Linear sweep
Start 3.0000V
Stop -5.0000V
Step - .1000V
Variable2:
VBODY -Vs2
Start 5.0000V
Stop .0000V
Step -1.0000V
Constants:
VDRN1 -Ch1 - .1000V

****** GRAPHICS PLOT ******

FIELD DIE 2,5 W/L 12u/1.2u

POLY GATE



Variable1:
VGATE -Vs1
Linear sweep

Start	3.0000V
Stop	-20.000V
Step	- .5000V

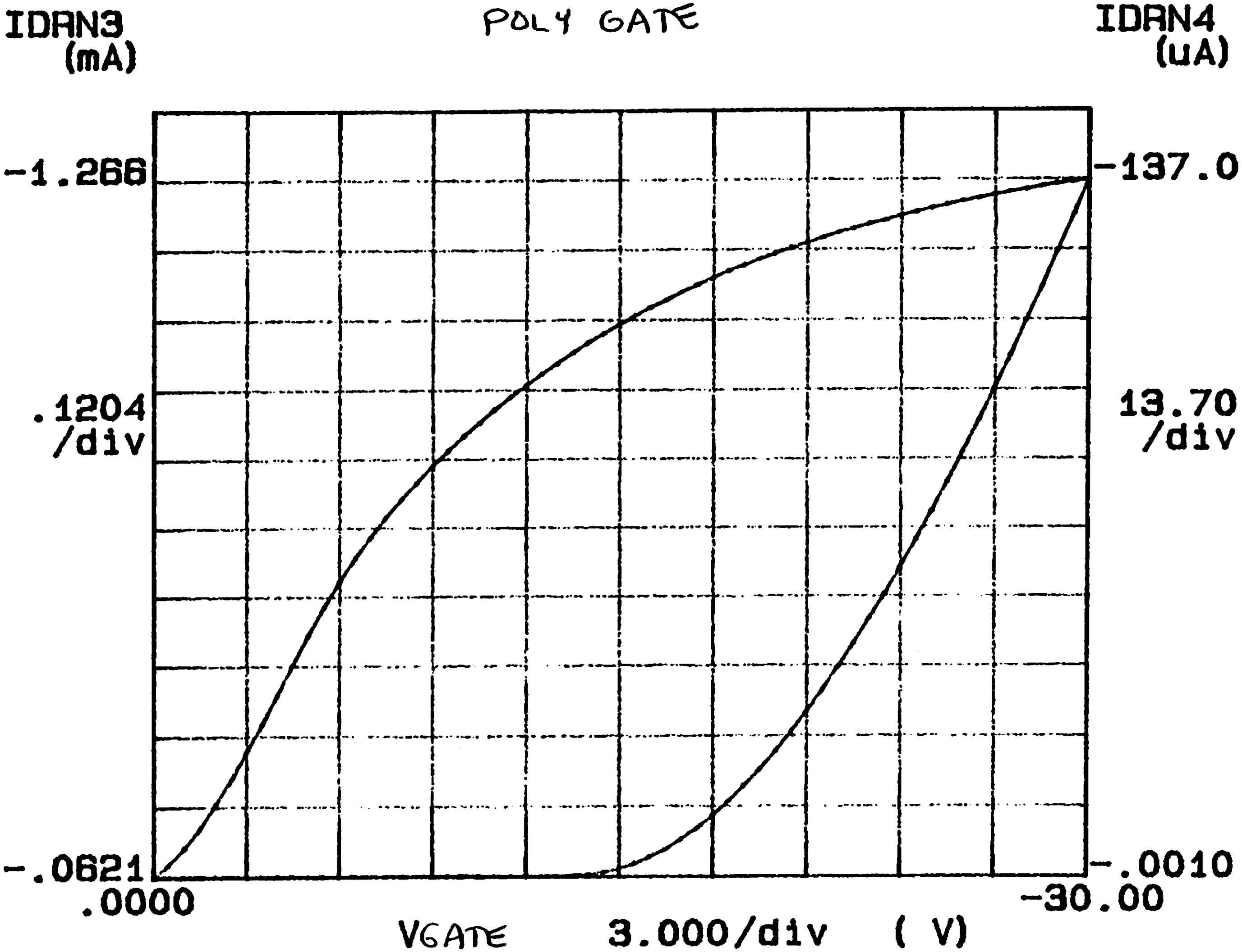
Constants:

VDRN1	-Ch1	-5.0000V
VBODY	-Vs2	.0000V

****** GRAPHICS PLOT ******

FIELD DIE2,5 W12u L2.4u 3u

POLY GATE



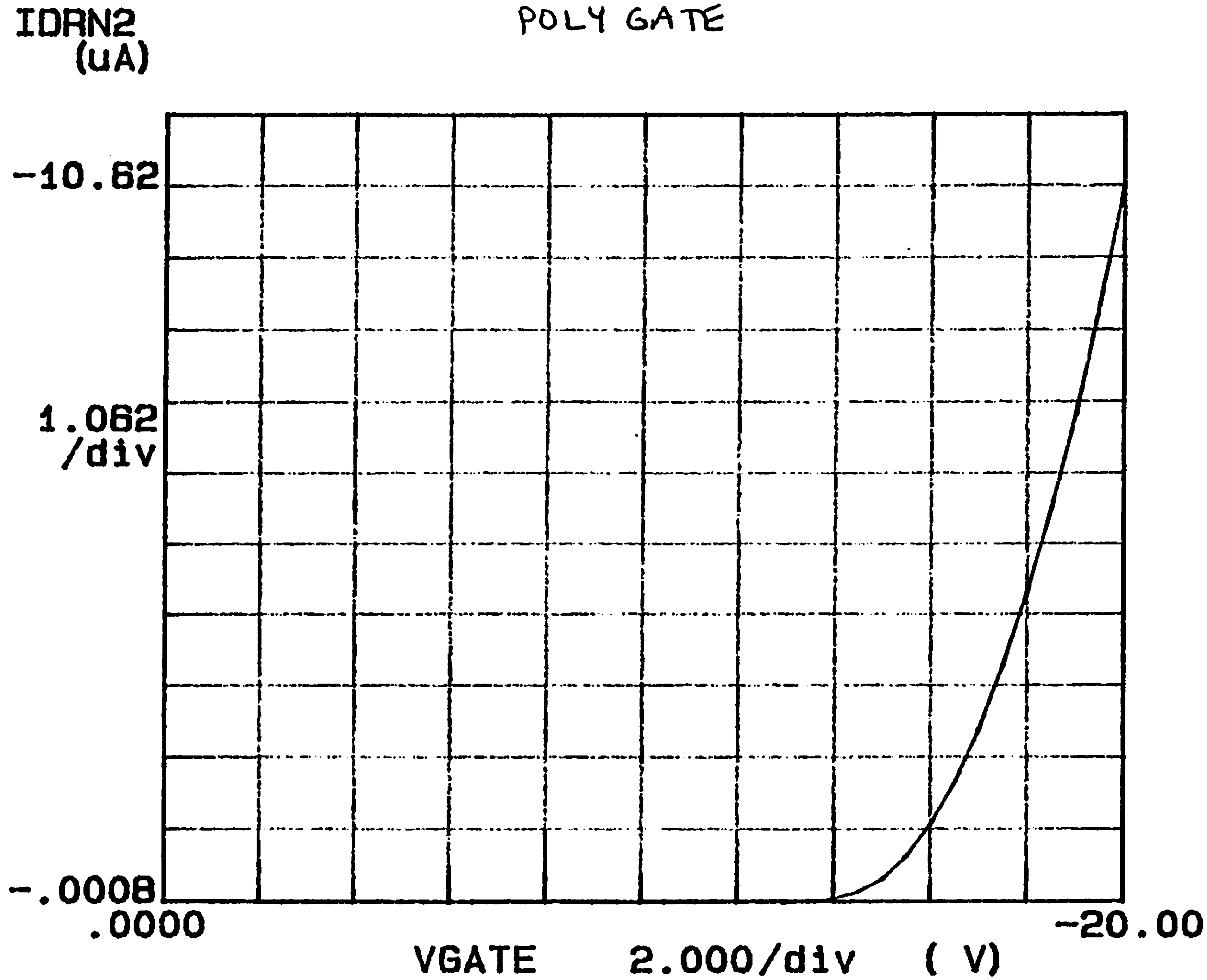
Variable1:
V -Ch1
Linear sweep
Start .0000V
Stop -30.000V
Step - .5000V

Constants:
VDRN3 -Ch3 -5.0000V
VDRN4 -Ch4 -5.0000V
VGATE -Vs1 .0000V
VBODY -Vs2 .0000V

****** GRAPHICS PLOT ******

FIELD DIE 2.5 W/L 12u/4.8u

POLY GATE

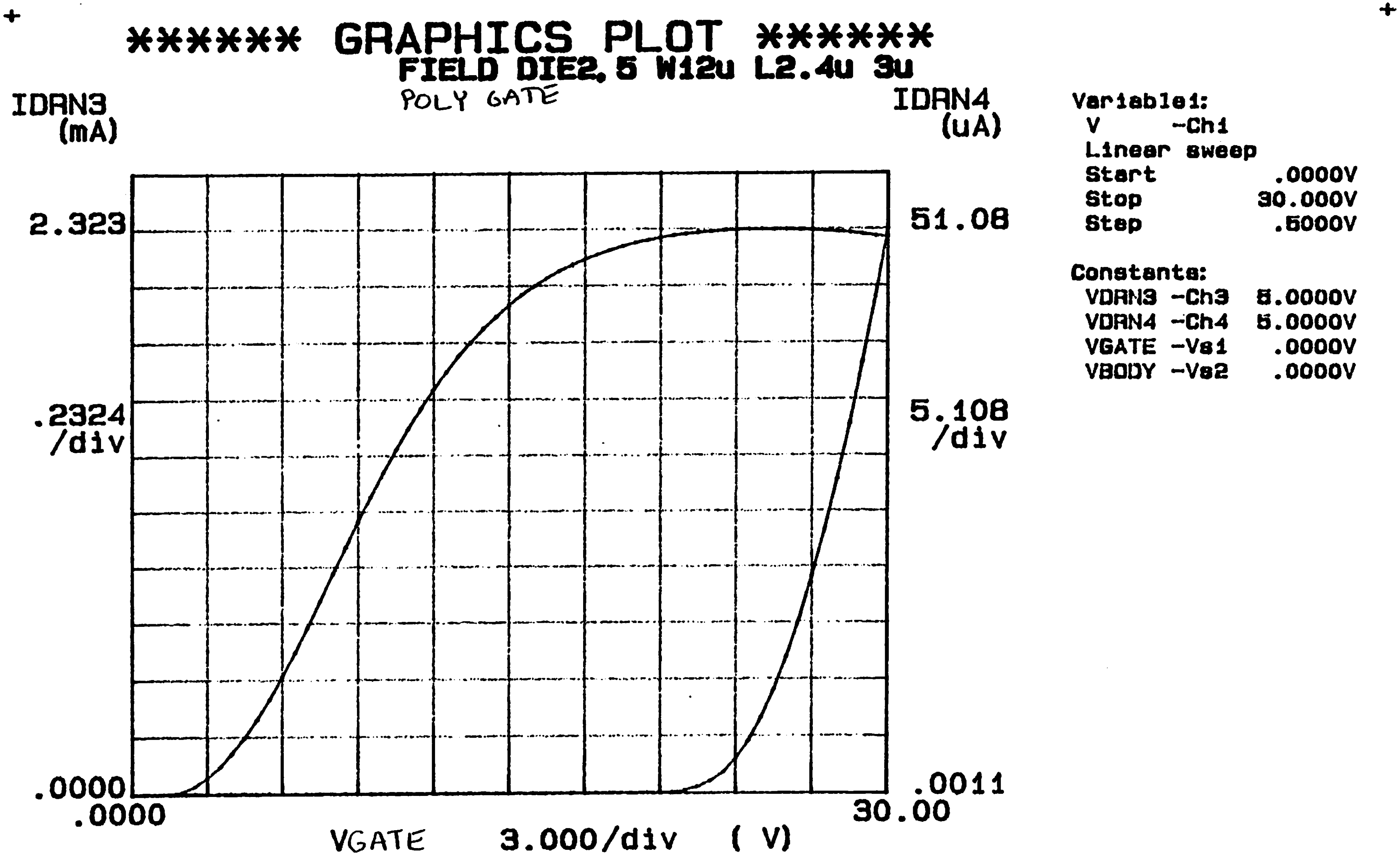


Variable1:
VGATE -Vs1
Linear sweep

Start	.0000V
Stop	-20.000V
Step	- .5000V

Constants:

VDRN2 -Ch2	-5.0000V
VBODY -Vs2	.0000V

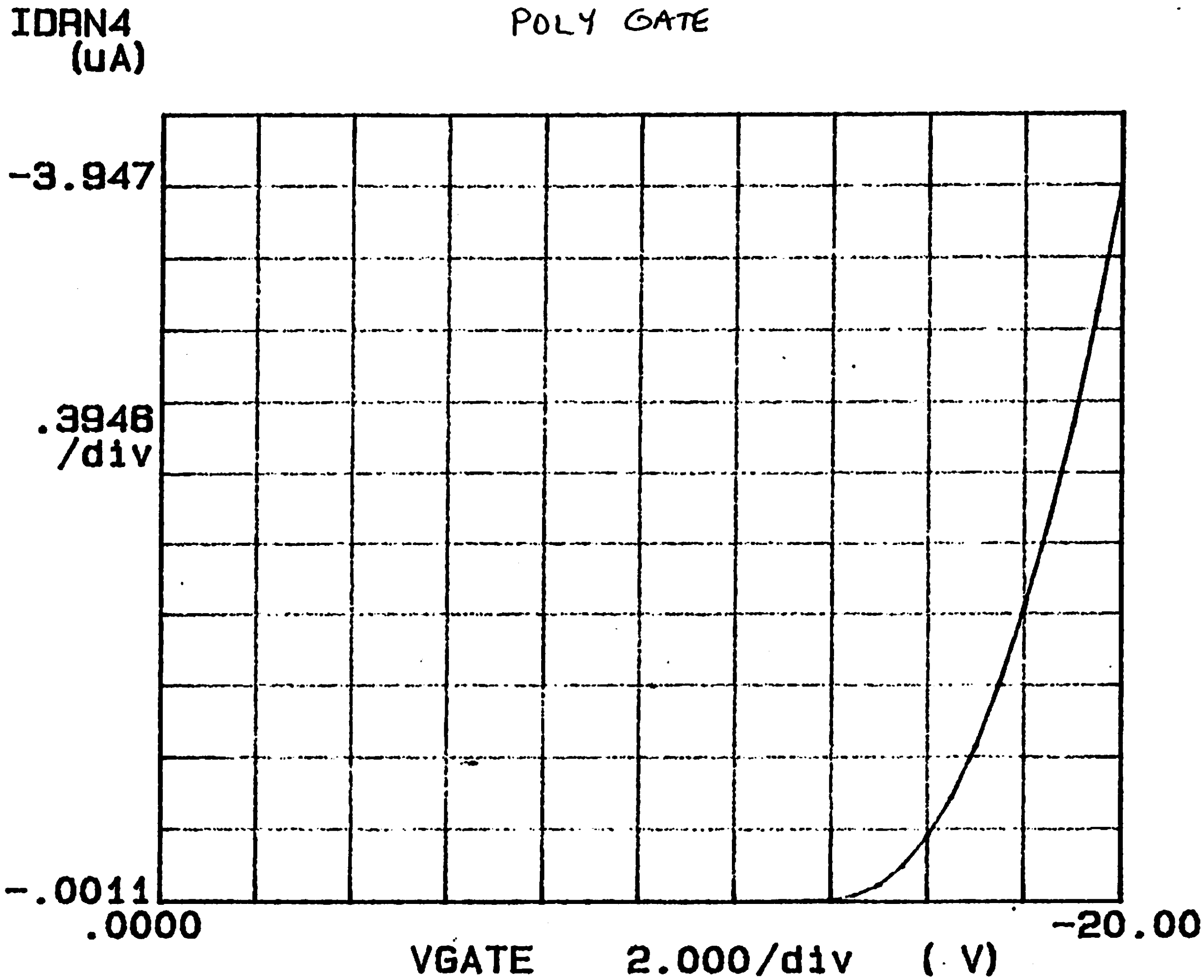


****** GRAPHICS PLOT ******
FIELD DIE2.5 W12u L2.4u 3u
POLY GATE
IDRN3
(mA)
IDRN4
(uA)
2.323
.2324
/div
.0000
51.08
5.108
/div
.0011
.0000
30.00
VGATE 3.000/div (V)
Variable1:
V -Ch1
Linear sweep
Start .0000V
Stop 30.000V
Step .5000V
Constants:
VDRN3 -Ch3 5.0000V
VDRN4 -Ch4 5.0000V
VGATE -Vs1 .0000V
VBODY -Vs2 .0000V

****** GRAPHICS PLOT ******

FIELD DIE 2.5 W/L 12u/12u

POLY GATE



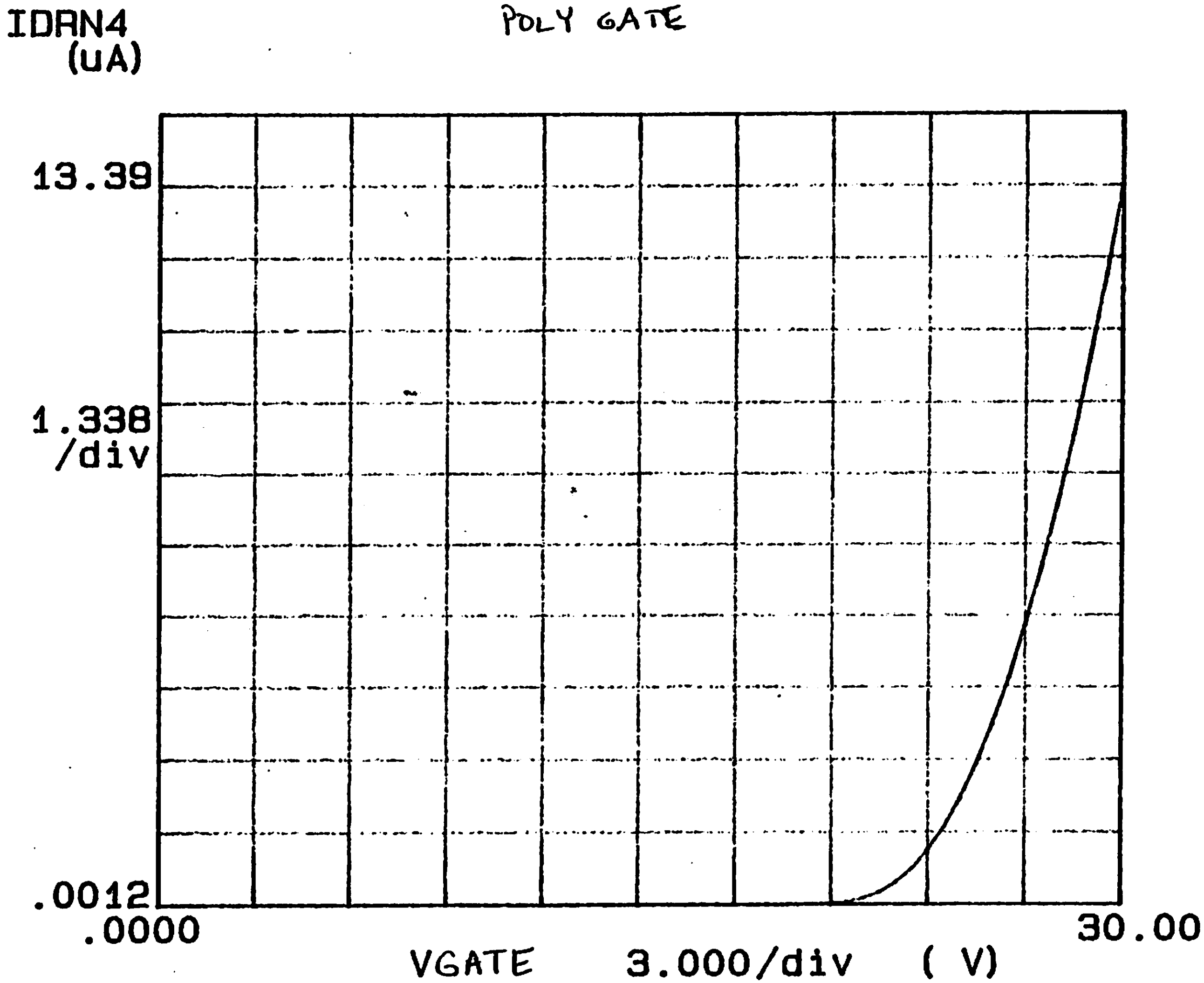
Variable1:
VGATE -Vs1
Linear sweep
Start .0000V
Stop -20.000V
Step - .5000V

Constants:
VDRN4 -Ch4 -5.0000V
VBODY -Vs2 .0000V

****** GRAPHICS PLOT ******

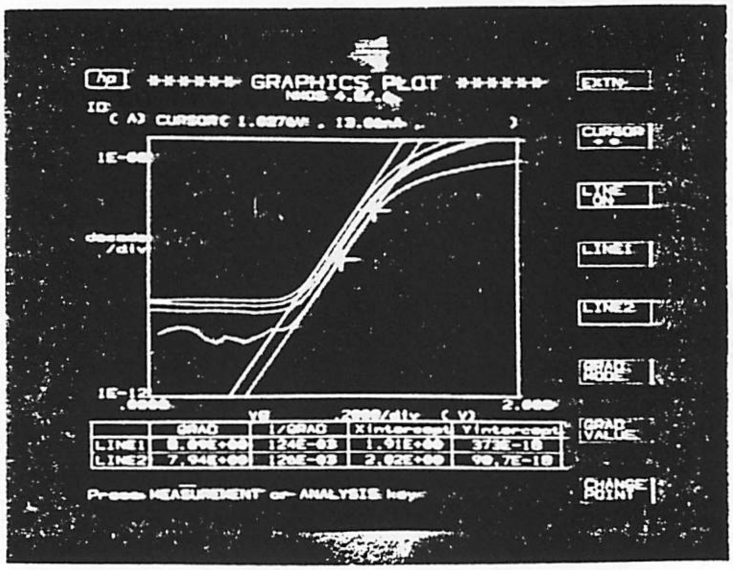
FIELD DIE 2,5 W/L 12u/12u

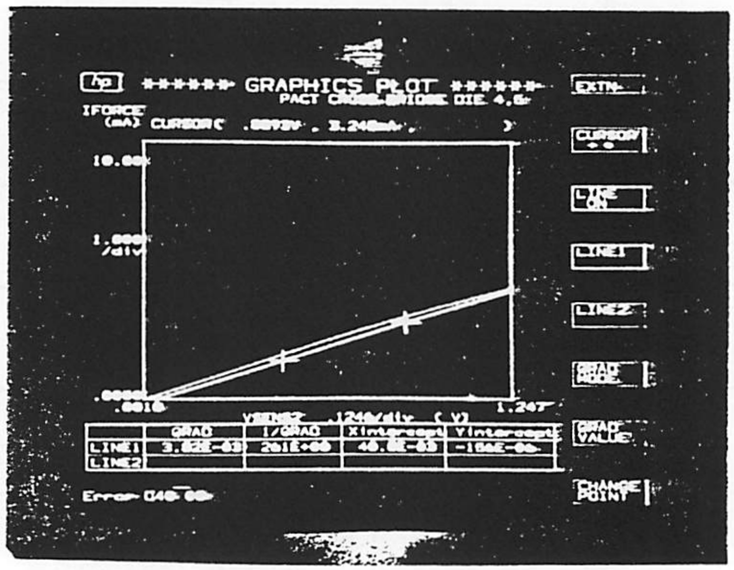
POLY GATE

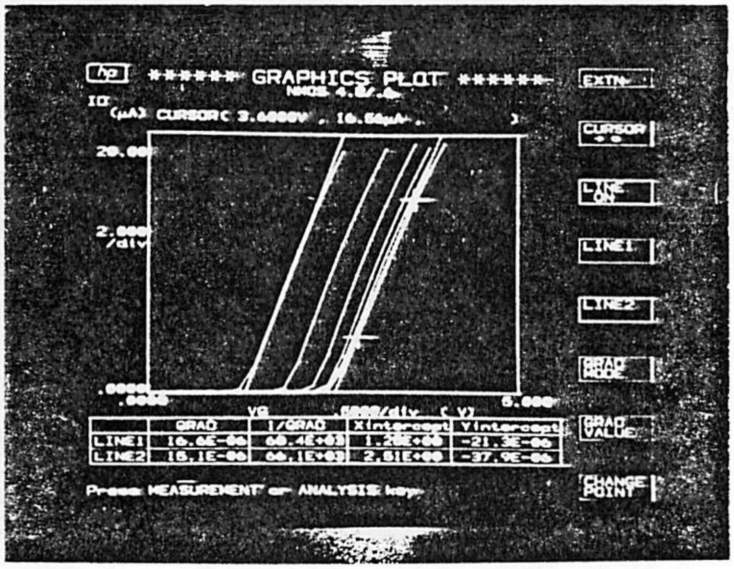


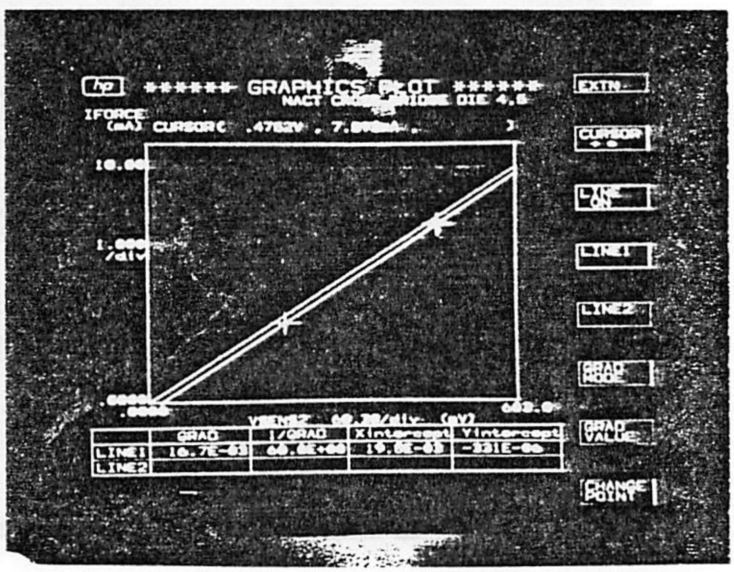
Variable1:
V -Ch1
Linear sweep
Start .0000V
Stop 30.000V
Step .5000V

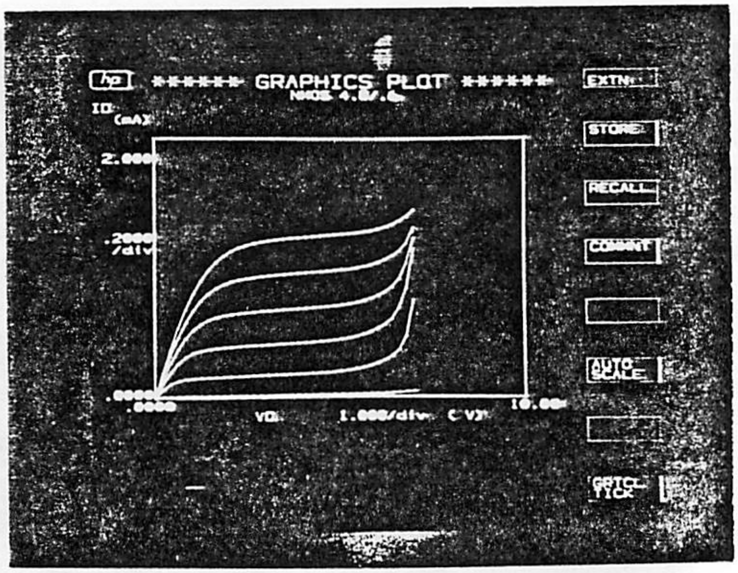
Constants:
VDRN4 -Ch4 5.0000V
VGATE -Vs1 .0000V
VBODY -Vs2 .0000V


GRAPHICS PLOT
CURSOR
EXTN
LINE ON
LINE1
LINE2
GRAD MODE
GRAD VALUE
CHANGE POINT
GRAD
1/GRAD
Xintercept
Yintercept
LINE1
LINE2
Press MEASUREMENT or ANALYSIS key

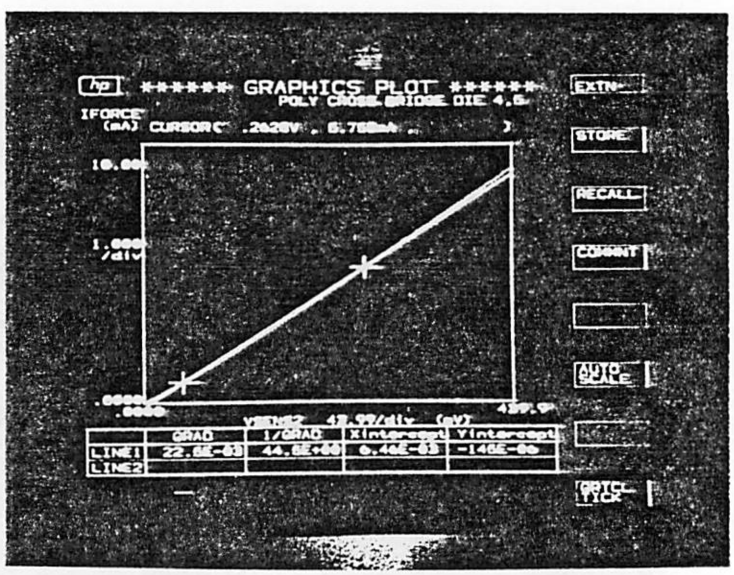

GRAPHICS PLOT
IFORCE
(mA)
CURSOR
EXTN
LINE ON
LINE1
LINE2
GRAD MODE
GRAD VALUE
CHANGE POINT
GRAD
1/GRAD
Xintercept
Yintercept
LINE1
LINE2


GRAPHICS PLOT
ID
(µA)
20.00
2.000
/div
5.000
GRAD
1/GRAD
Xintercept
Yintercept
LINE1
LINE2
Press MEASUREMENT or ANALYSIS key
EXTN
CURSOR
LINE ON
LINE1
LINE2
GRAD MODE
GRAD VALUE
CHANGE POINT

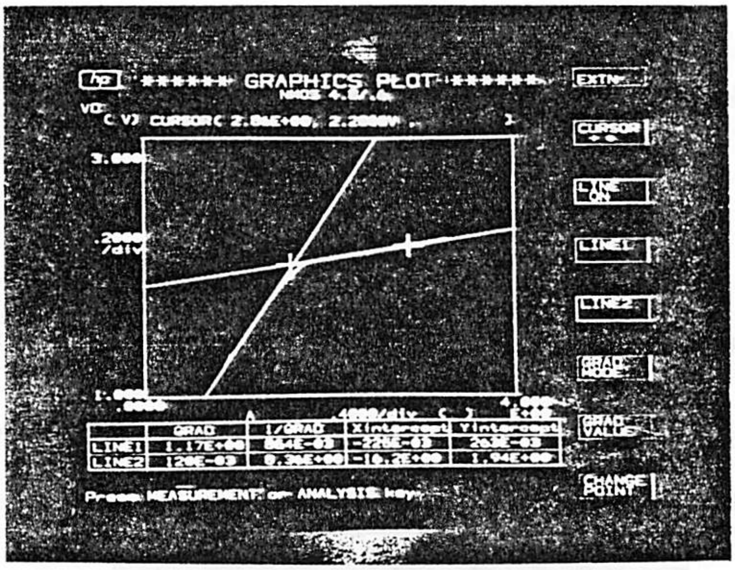

GRAPHICS PLOT
IFORCE
(mA)
CURSOR(.4762V
10.00
1.000
/div
GRAD
1/GRAD
Xintercept
Yintercept
LINE1
LINE2
EXTN
CURSOR
LINE ON
LINE1
LINE2
GRAD MODE
GRAD VALUE
CHANGE POINT



GRAPHICS PLOT
ID
(mA)
2.000
.2000
/div
.0000
.0000
VD
1.000/div
(V)
EXTN
STORE
RECALL
COMMNT
AUTO SCALE
GRTCL TICK



GRAPHICS PLOT
POLY CROSS BRIDGE DIE 4.5
IFORCE
(mA)
CURSOR
1.000
/div
.0000
.0000
VSENSE2
(mV)
GRAD
1/GRAD
Xintercept
Yintercept
LINE1
22.6E-03
44.6E+00
LINE2
EXTN
STORE
RECALL
COMMNT
AUTO SCALE
GRTCL TICK


GRAPHICS PLOT
EXTN
CURSOR
LINE ON
LINE1
LINE2
GRAD MODE
GRAD VALUE
CHANGE POINT
GRAD
1/GRAD
Xintercept
Yintercept
LINE1
1.17E+00
-220E-03
LINE2
120E-03
-16.2E+00
1.94E+00
Press MEASUREMENT or ANALYSIS key

Berkeley 1.25 μm CMOS Process Run#1 Summary

Albert T. Wu

Ping K. Ko

Four wafers were finished in the first test run. They are denoted as TW1, W2, W3 and W4.

1. Ion Implantation:

1.1. Well Implant (Phosphorus):

Wafer	Implant Planned	Implant Received
TW1	150KeV,2e12	150KeV,3.75e12
W2	150Kev,1.5e12	150KeV,2.8e12
W3	150KeV,2e12	150KeV,3.75e12
W4	150KeV,2e12	Uncertain

well measurement:

Rs=1.43e3 ohms/square

x_j=3 μm (probably erroneous)

C_s=2.0e16 cm^3 ± 10% (probably erroneous)

1.2. Field Implant (Boron):

Wafer	Implant Planned	Implant Received
All	100KeV,1.0e13	100KeV,1.9e13

1.3. Capacitor Bottom Plate Implant (Arsenic):

Wafer	Implant Planned	Implant Received*
W2 & W3	100KeV,1.3e15	100KeV,2.5e15

1.4. Threshold Adjust Implant (Boron):

* The received implant dose is 1.9 times that of planned dose due to ion implanter correction factor calibration error at time of implantation.

Wafer	Implant	Planned
TW1	30KeV,2.3e12	30KeV,4.3e12
W2	30KeV,1.0e12	30KeV,4.3e12
W3	30KeV,2.3e12	30KeV,4.3e12
W4	30KeV,1.0e12	30KeV,1.9e12

1.5. N+ Source/Drain Implant (Arsenic):

All wafers, Implant Planned = Implant Received = 100 KeV, 3e15

1.6. P+ Source/Drain Implant (BF_2):

All wafers, Implant Planned = Implant Received = 50 KeV, 2e15

2. Other Process Measurement Data:

2.1. Field Oxide Thickness After LOCOS (step H):

Target: 6500A

Measured: 6600 A ± 50 A

2.2. Gate Oxide Thickness:

Target: 250A

Measured: 262 A ± 2.5A

2.3. Poly Thickness Measurement:

Target: 4000A

3950 A ± 100 A

Rs=25 ohms/square

2.4. BPSG

Target: Thickness = 7500A, Boron ~ 4%, Phosphorus ~ 7%

Measured: Thickness = 8500 A, Boron and Phosphorus concentration unknown

3. MOSFET Device Measurement:

3.1. Threshold Voltages at zero backgate bias:

Wafer	V_{tno}	V_{tpo}	Field V_{tno}	Field V_{tpo}
TW1	1.49	Buried Channel	25.9	-16.5
W2	1.43	Buried Channel	25	-13.7
W3	1.46	Buried Channel	22.2	-15.5
W4	0.85	Buried Channel	>30	see (1) & (2)

(1) The p-channel devices are all buried channel type devices which cannot be turned off at zero backgate bias. Among the four wafers, the p-channel devices of TW1, W2 and W3 can be turned off by applying a backgate bias of 2 volts. But the p-channel devices of W4 can never be turned off.

(2) The p-channel field devices of W4 behave abnormally. They cannot be turned off even with high backgate biases. Our suspicion is that the implant dose for the well of W4 may be too low such that surface becomes p-type after the Vt implant.

3.2. Dopant Profiling Of Channel:

The doping profiles of the n-channel devices of various test wafers were determined from threshold voltage measurement as a function of the backgate bias. It was found that the integral dose is only 70% of the implant dose. This discrepancy is common to all four wafers. This phenomenon must be monitored in future runs.

3.3. Subthreshold Turn-on Slope of NMOS Devices:

The subthreshold slope of the NMOS devices is ~120 mV/decade. This corresponds to a surface state density of about 2e11 cm^{-2}. This observation plus the fact that the dielectric breakdown strength is less than 5 MV/cm suggest that further work has to be done on the gate oxidation module.

4. MOS C-V Measurement:

4.1. Quasi-static C-V:

(1) The surface state density was estimated to be of the order of 2e11 cm^{-2}, consistent with the results from 3.3. above. The surface states were acceptor type.

(2) Quasi-static C-V measurements on n-well region gate capacitors shows p-type substrate behavior, indicating a deep buried p-type surface in the n-well area.

5. PN Junction Measurement:

Reverse Bias Leakage Current = 2 nA/cm^2

Reverse Bias Breakdown Voltage = 12.6 Volt

6. Discussion:

6.1. Implant Doses:

From the device threshold voltages, it is concluded that the implant doses were all too high. This was due to the wrong correction factor for the new 4" end station on the ion implanter. From simulation results and the only 2 available data points, we estimate that the design doses are about right.

6.2. Gate Oxidation Process:

The gate oxide formed in the first run has a high density of acceptor type surface states. Possible causes include:

(1) The coating of photoresist on the gate oxide after gate oxidation for the polysilicon backside gettering, and the later piranha cleaning step may have deterioated the gate oxide.

(2) The gate oxide was design to be grown in 200 sccm of TCA saturated nitrogen and 4 lpm of oxygen. The equivalent HCl concentration is about 2%. But the TYLAN furnace recipes did not specify the TCA flow rate. Thus the actual HCl concentration in the first run is unknown. Also, the oxidation temperature was designed to be 950 ° C, which may be too low for adequate TCA oxidation.

For future runs, a short loop gate oxidation trial run is recommended.

6.3. Gettering:

The PN junction reverse bias leakage current is low, on the order of 2 nA/cm^2. The heavy metals were effectively gettered. There is no indication whether the gettering is mainly due to internal oxygen precipitation or backside polysilicon gettering.