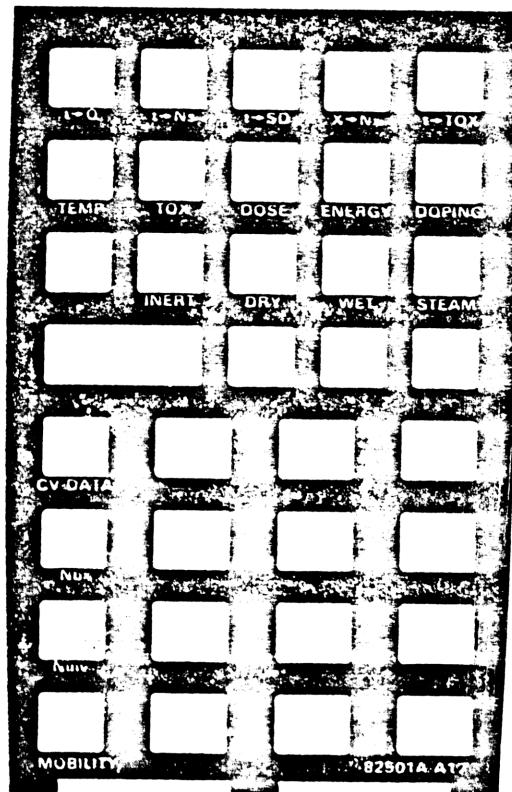


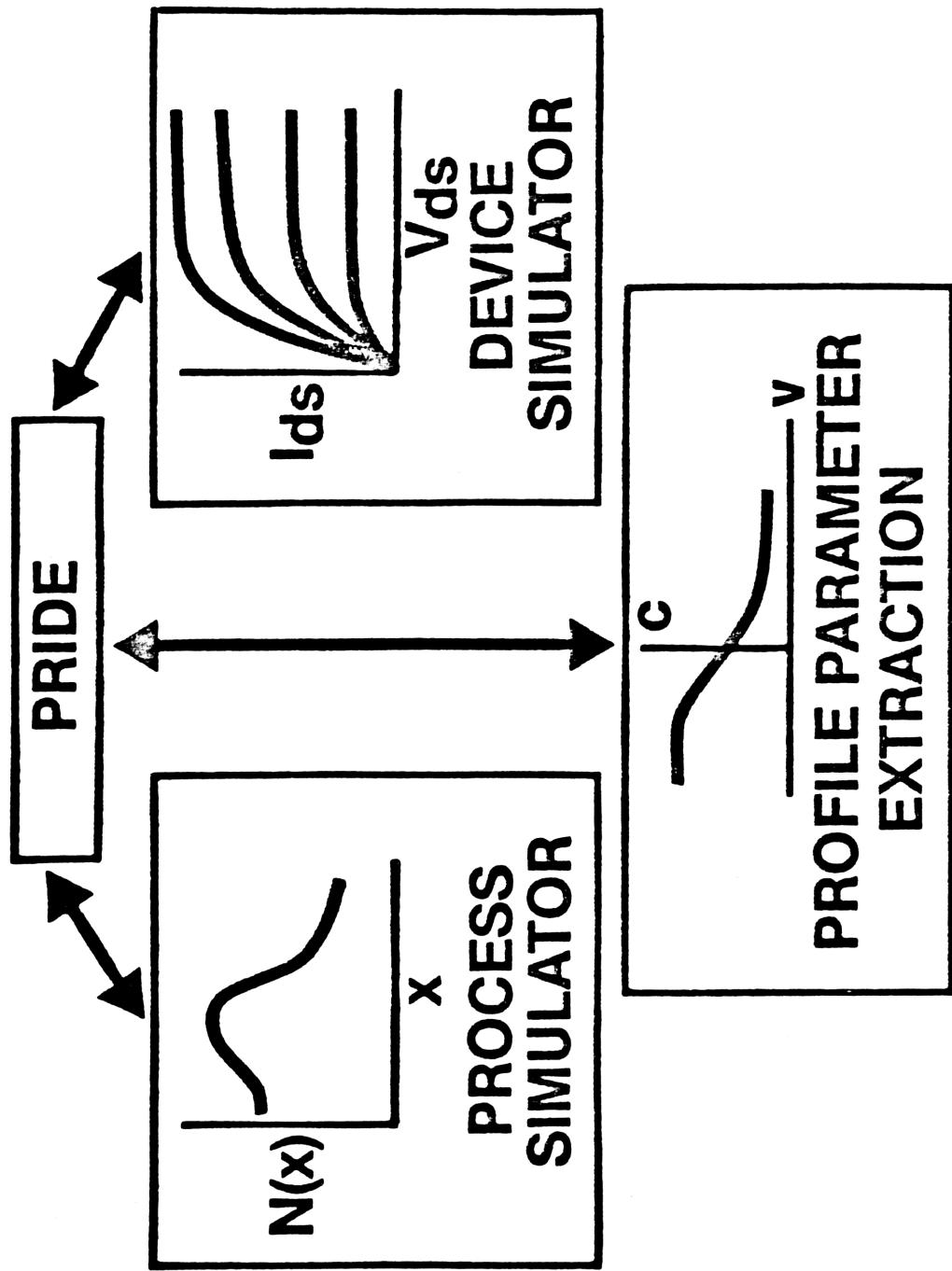
***PRIDE - Portable Process and Device Design**

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August 1981**

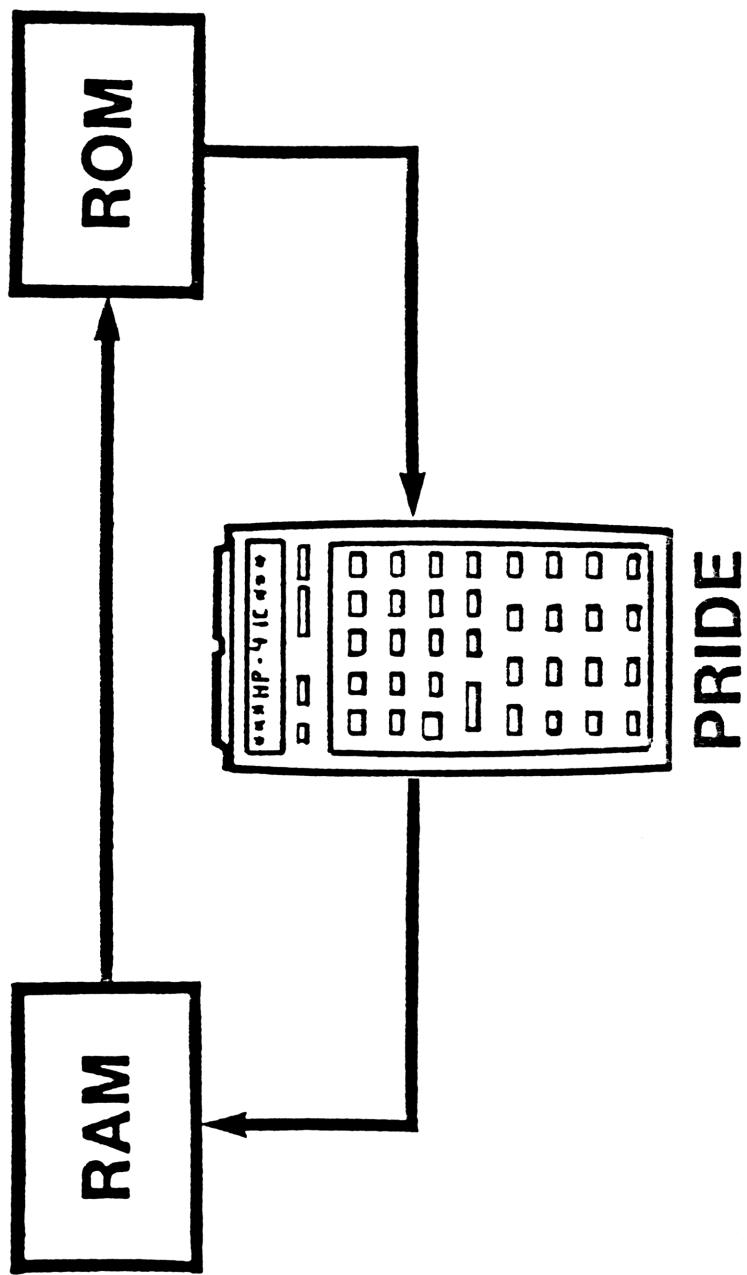


ABSTRACT

An efficient combination of analytical and numerical methods, PRIDE (Portable Process and Device Design) is a program written for the HP41-CV handheld calculator. It is compact, easy to use, and provides accuracy similar to numerical techniques. PRIDE integrates both process and device design by offering thermal oxidation calculations, chemical deposition and ion-implantation doping profile calculations, parameter extraction routines, and IGFET device analysis. IGFET channel profiles are calculated for multiple thermal steps including oxidizing conditions and fitted to a box profile to determine threshold voltage or a gaussian profile to determine subthreshold behavior and threshold voltage shifts relative to an unimplanted IGFET. Alternatively, threshold data is converted to box profile parameters to determine suitable process conditions. The ability to solve for oxidation time or oxide thickness and drive-in time or junction depth allow easy design for fixed process conditions. PRIDE may be used in a preprogrammed or interactive mode and is easily modified or enhanced for differences in process coefficients or analytical models. In addition, plotting capabilities provide quick visual inspection for process and device analysis. A five thermal step NMOS process modeled using PRIDE shows excellent agreement with results from SUPREM for the channel concentration profile. PRIDE may be used as a rapid handheld optimizer for IGFET processes by offering immediate access to process and device simulation models thereby reducing process development time.



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IGFET DEVICE SIMULATION:

- * GAUSSIAN TO BOX PROFILE DETERMINATION**
- * THRESHOLD VOLTAGE CALCULATIONS**
- * SUBTHRESHOLD BEHAVIOR CALCULATIONS**
- * DRAIN-TO-SOURCE CURRENT CALCULATIONS**

PROCESS SIMULATOR:

- * THERMAL OXIDATION**
- * CHEMICAL PROFILES**
- * ION IMPLANTATION PROFILES**
- * PROCESS PARAMETERS**

PROCESS PARAMETERS:

- * SILICON VACANCY CONCENTRATION**
- * IMPURITY DIFFUSION COEFFICIENTS**
- * INTRINSIC CARRIER CONCENTRATION**

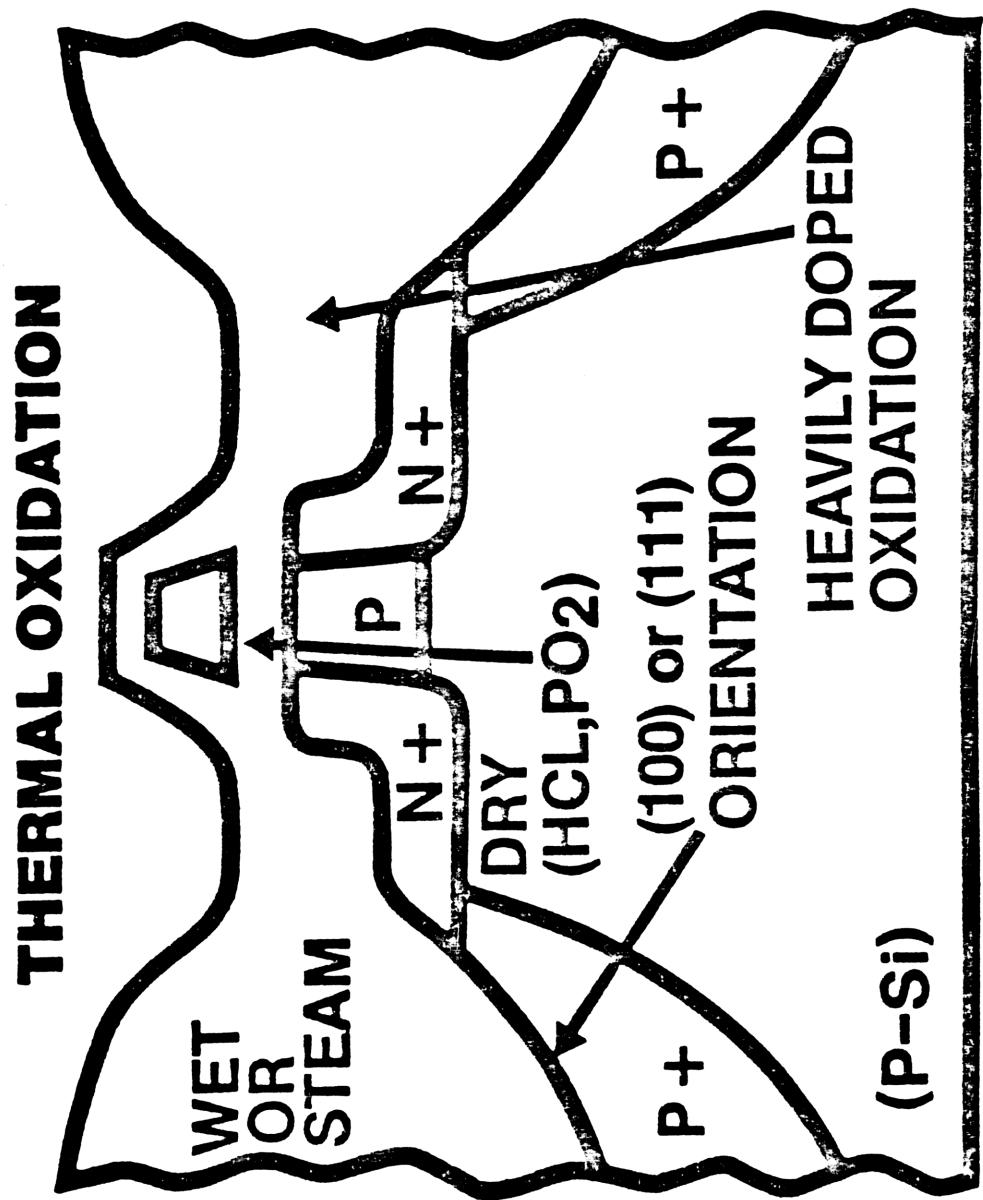
INTRODUCTION

PRIDE is an analytical device and process simulator written for the HP41-CV handheld programmable calculator which may be used to calculate oxide thickness, source/drain diffusions, and drive-in profiles for chemical or ion-implanted predepositions, as well as determine threshold voltages and subthreshold behavior for unimplanted/implanted enhancement-mode IGFETs. In addition, measurement routines are available to analyze CV and threshold data to determine such parameters as Nb, Tox, Vfb, and the box height and width for an implanted enhancement-mode IGFET.

The oxide calculations account for the choice of dry, wet, or steam oxidation with the capability to handle heavily doped substrates and partial pressure of oxygen. In addition, an empirical fit for a single dry oxidation step using HC1 is provided for 900 degrees C, 1000 degrees C, and 1100 degrees C for HC1 greater than or equal to one percent of the total gas flow. One may solve for the time to grow a specified amount of oxide thickness grown. Multiple steps to grow oxide using different ambient conditions enable one to model a dry-wet-dry oxidation for example. One specifies the silicon substrate orientation (111,100) by using the ORIENT key. The ambient conditions are entered via the keyboard thereby eliminating needless prompting of questions to the user. As a consequence, once a value is entered, it need not be entered again unless a change in value is desired. Flags are used to denote special oxidation conditions such as the use of HC1, partial pressure of oxygen, and heavily-doped oxidation. Of these three conditions, only the first two must be specified for each oxidation step for multiple thermal cycle modeling. The CLEAR key allows one to remove all oxide grown from previous steps as well as initialize default conditions (no HC1, no partial pressure of oxygen, lightly-doped oxidation) for oxidation modeling.

Heavily doped implanted arsenic or boron (source/drain) diffusions for inert ambient conditions are modeled by the t>SD key. By specifying dose, temperature, dopant type, and the time for the drive-in diffusion, the junction depth, sheet resistance, and surface concentration may be calculated. Alternatively, the drive-in time can be determined by specifying the desired junction depth. The equations used to model the arsenic or boron profiles are based upon the work by R.B. Fair.

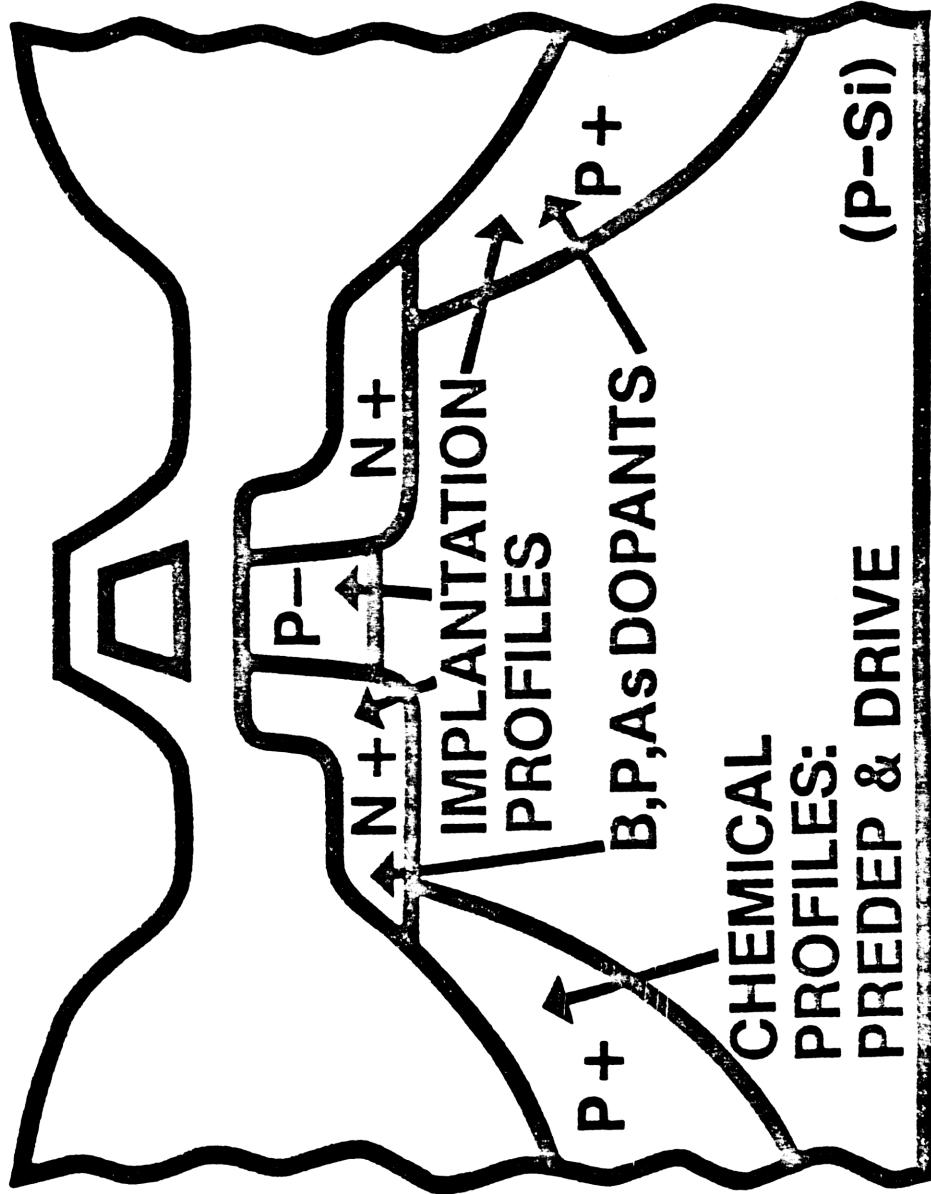
Using PRIDE one can also model the thermal redistribution of ion-implanted or chemically predeposited boron, phosphorous or arsenic, assuming inert or oxidation ambient conditions. Chemical predepositions are calculated by use of the t>Q key which determines the amount of charge introduced into the silicon by specifying drive-in conditions and the time for the predeposition. Conversely, one may submit a specified charge and calculate the required time by the use of the Q>t key.



Chemical drive-in diffusions are modeled as a half gaussian function with the peak occurring at the silicon-silica interface for inert ambient conditions. For oxidizing ambients, a coordinate shift of .44 times the oxidation thickness grown is taken into account as well as the oxidation enhanced diffusion coefficient. The t>Ns key is used to calculate the surface concentration value by entering the time for the diffusion in the HH.MMSS format. Ion-implanted profiles are determined using the same t>Ns key with the dose and energy of the implanted species entered via the key-board by the use of the DOSE and ENERGY keys. The analytical models used for the ion-implanted profiles are based upon the work by Hee-Gook Lee. Reflection and segregation effects are taken into account as well as the oxidation enhanced diffusion coefficients. To calculate the profile for an IGFET channel profile using multiple inert ambient thermal cycles, one would enter the oxide thickness (if implantation is performed through an existing oxide screen); type of dopant atom (boron, phosphorous, arsenic); dose and energy of the implanted species (range and straggle are calcualted by a power curve fit to the LSS range statistics) or one may enter independent values for Rp, dRp, and Imax from the keyboard; and the temperature and time for the drive-in thermal cycles. The t>Ns key is cumulative so that the modeling of multiple thermal cycles is possible. The field implant profile for an NMOS process may be modeled by specifying the type of oxidation ambient. The program automatically calculates the oxide thickness grown during that thermal cycle and adjusts for the new coordinate system by subtracting off .44 times the thickness of the new oxide to account for the silicon volume used. Inert ambient thermal cycles performed after an oxidation ambient drive-in are modeled by assuming a gaussian curve fit to the previous profile. The user is then required to enter the curve-fitted values for Rp, dRp, and Imax. Similarly, if an oxidation ambient cycle follows an inert cycle, the previous profile is also curve-fitted to a gaussian profile as the input profile.

The Nx>X key (used to determine junction depth when an arbitrary concentration is specified) and the X>Nx key (used to plot the profile) may be used for any of the above drive-in thermal cycles including source/drain drive-in, chemical predeposition, chemical drive-in, and ion-implanted drive-in cycles, as well as the as-implanted profiles. Keys are also provided to calculate intrinsic carrier concentration, silicon vacancy concentration, and impurity diffusion coefficients as a function of specified ambient conditions.

CONCENTRATION PROFILES

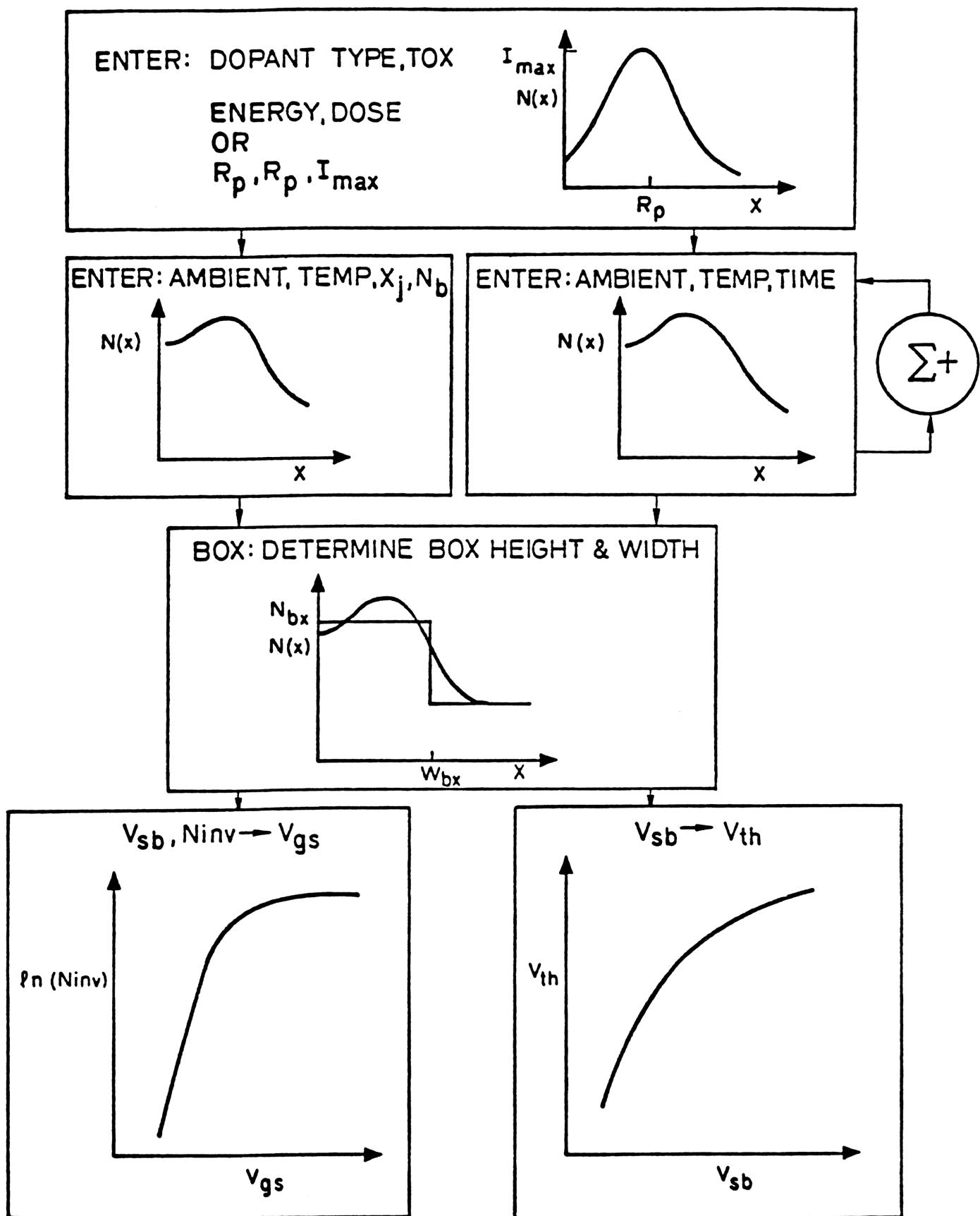


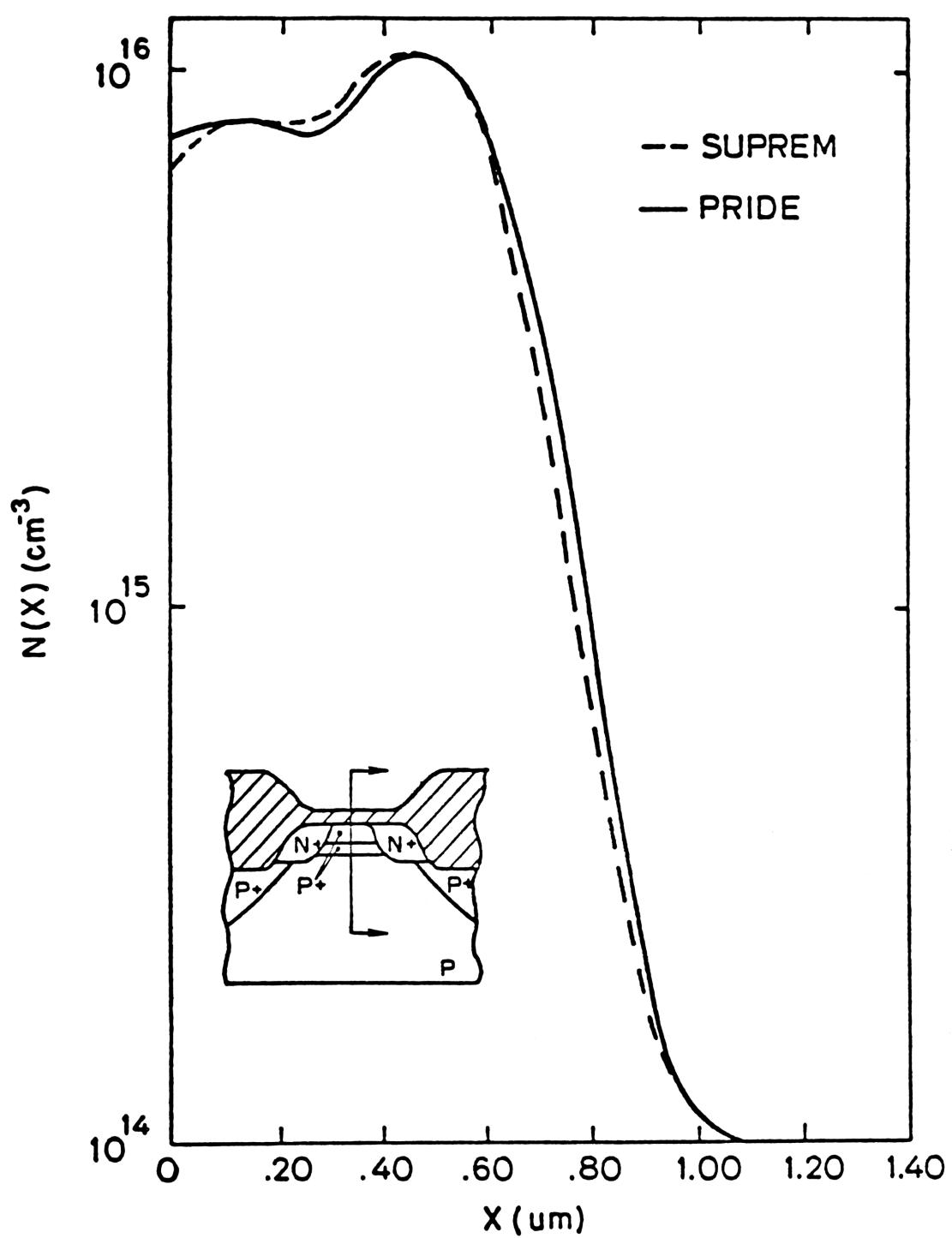
Once the channel profile is determined for an ion-implanted enhancement-mode IGFET, the threshold voltage for an unimplanted/implanted IGFET may be calculated. The ion-implanted channel profile may be approximated by a single box profile whose height (N_{bx}) and width (W_{bx}) are determined by the BOX key. This capability not only provides parameters to model device characteristics, but allows one to more easily characterize process changes and modifications for an NMOS process. $V_{sb} > V_{th}$ key is then used to calculate threshold voltage as a function of substrate bias voltage. Alternatively, the profile may be treated as a gaussian concentration profile to determine the subthreshold behavior curves (inversion charge density as a function of gate to source voltage minus the flatband voltage for a specified back bias voltage condition) by use of the $N_v > V_g$ key or the threshold voltage shift relative to an unimplanted IGFET by use of a built-in subroutine called "dVT". The model used for the above device analysis is based upon the work by J.R. Brews. The drain to source current (I_{ds}) is modeled by use of the charge control equations whereby the user submits the value for W/L , Tox , mobility, V_{gs} , and V_{th} to obtain the I_{ds} values as a function of V_{ds} . The box parameters (W_{bs} , N_{bx}) may be determined by the BOX key, entered independently by the user, or determined by the V_t -DATA key (see below). This provides great flexibility for the user for determining the device characteristics.

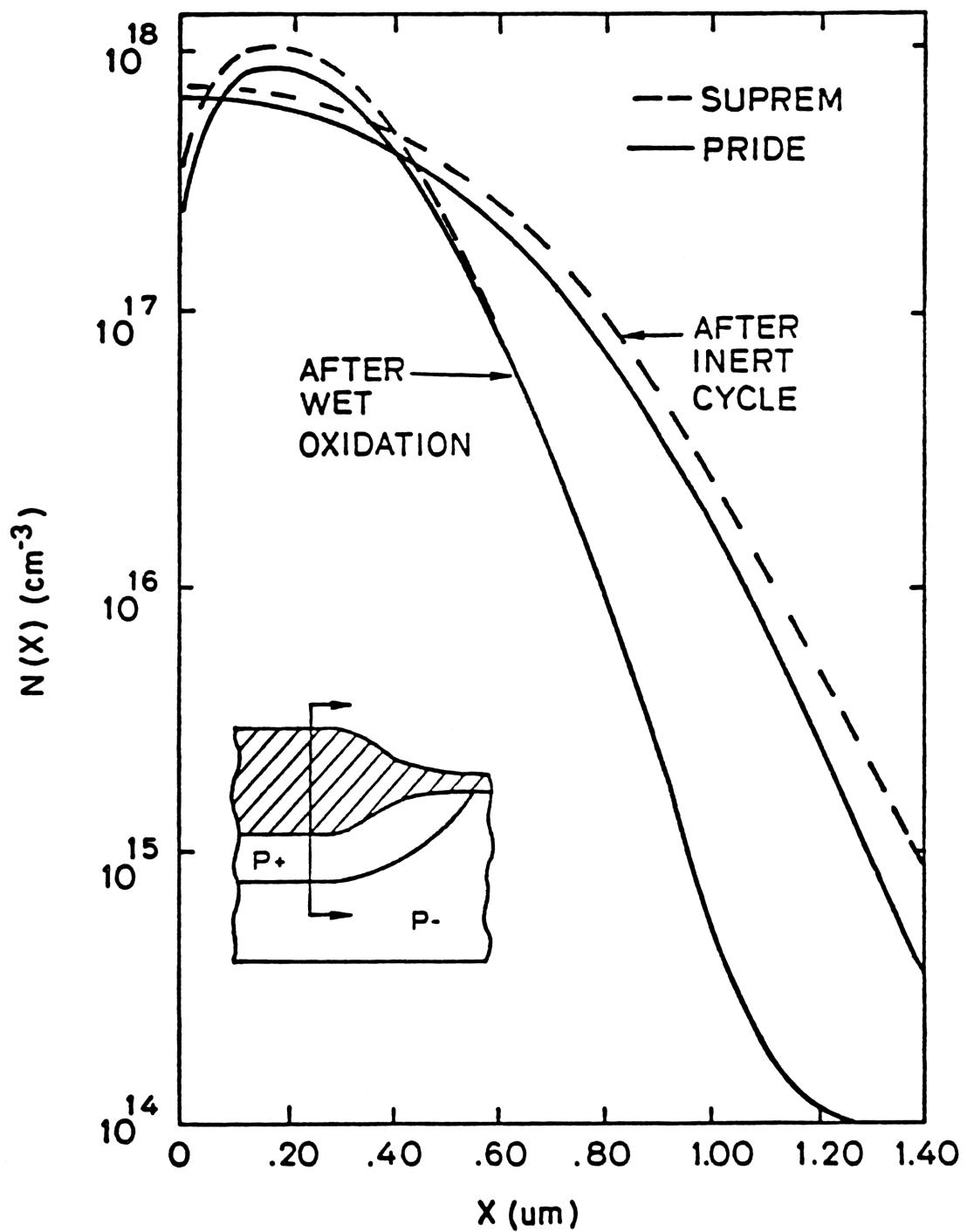
A measurement extraction key (V_t -DATA) is provided to determine the curve-fitted values for V_{fb} and N_b for an unimplanted enhancement-mode IGFET. CV analysis is provided by the use of the CV-DATA key which determines Tox , C_{fb} , and N_b for a large test capacitor. The initial size of 100 registers (the minimum number of registers required for PRIDE) allows fourteen pairs of threshold data to be used as inputs. By simply sizing the register allocation greater than one hundred registers allows one to examine a larger number of data points.

PRIDE may be used to transform the HP41-CV handheld calculator into a powerful processing and IGFET device analysis tool. The use of a custom overlay provides a fast and efficient means to input various types of data thereby minimizing needless prompting of questions to the user. Only those parameters that change for subsequent operations need to be entered. In addition, the sequence of key strokes is unimportant making PRIDE a very easy tool to use. The use of an INIT key makes the program totally general and easily adaptable to any known process by allowing the user to replace default values for process coefficients (such as linear rate oxidation exponential coefficients) or subroutine names used by PRIDE to replace analytical models used by PRIDE. The minimum number of data registers required for PRIDE is 100. When the HP 82143A peripheral printer is used with the HP41-CV calculator, the user can obtain plots for I_{ds} , V_{th} , Tox , $N(X)$, N_{inv} , S_{iv} , D_i , and n_i by use of PLOT key.

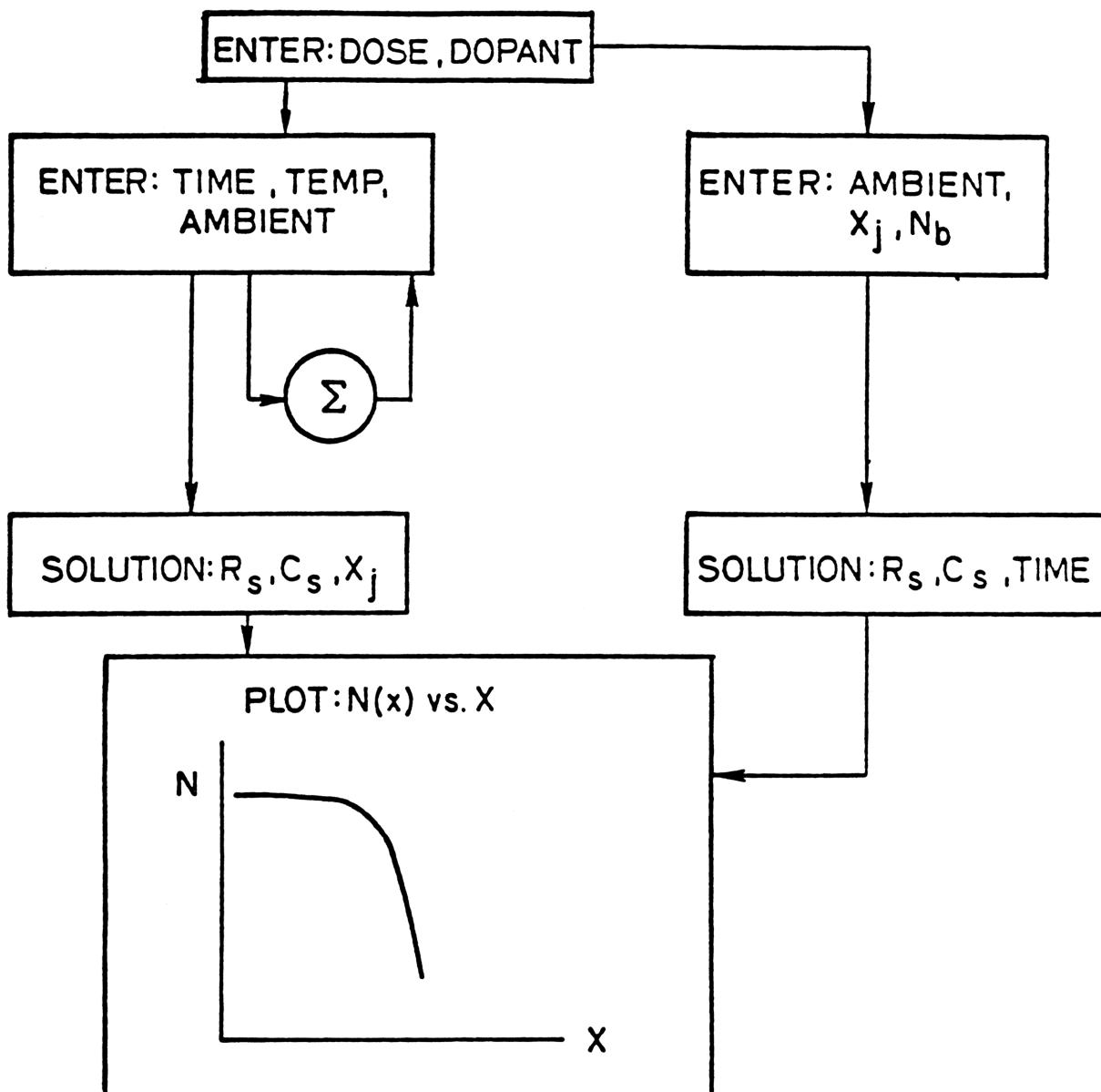
IGFET CHARACTERIZATION





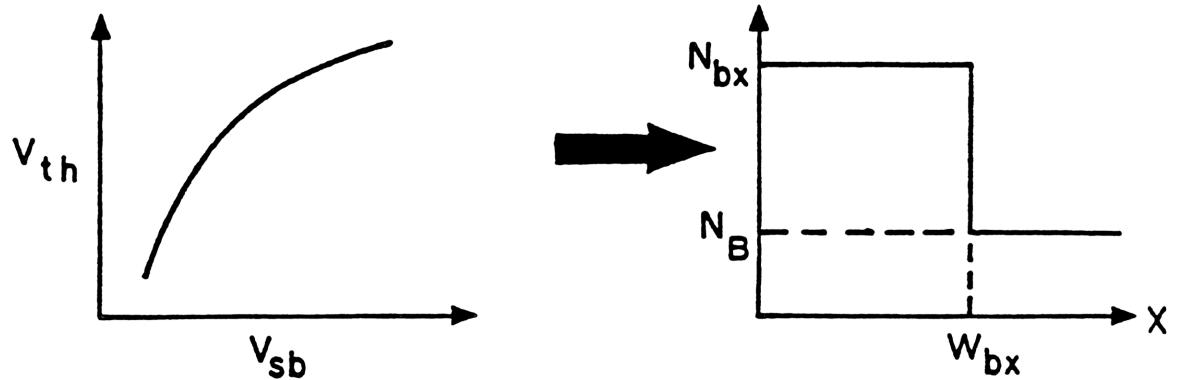


SOURCE / DRAIN OPTIMIZATION

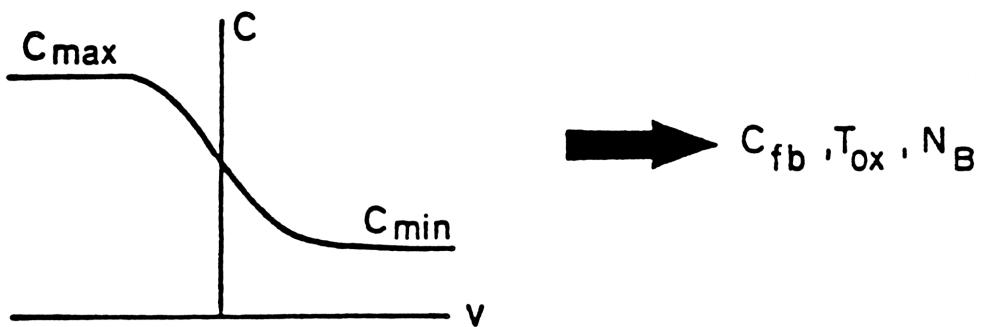


MEASUREMENT ROUTINES

THRESHOLD DATA: V_{fb} , N_b , N_{bx} , & W_{bx}



CV DATA: YIELDS C_{fb} , T_{ox} , & N_b (GIVEN: C_{max} , C_{min})



***INITIALIZATION**

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Turn on calculator		hit ON	WORKING
2	Toggle USER key to leave user mode		hit USER	
3	Size the data registers to at least 100 registers (N=100)	N	XEQ ALPHA SIZE ALPHA N	SIZE=N
4	Toggle USER key to return to user mode		hit USER	
5	Initialize PRIDE program		hit INIT	INITIALIZE **PRIDE***
<p>*NOTE: As long as memory is not lost, this routine need only be performed once.</p>				

OXIDATION MODELING

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Clear oxide register		hit CLEAR	CLEAR
2	Select oxidation ambient (Dry,Wet,Steam)		hit DRY hit WET hit STEAM	DRY OXID WET OXID STEAM OXID
3	Enter temperature (degree C)	T1	hit TEMP	TEMP=T1
4	Enter silicon orientation	nnn	hit ORIENT	ORIENT=nnn
5	(Optional) partial pressure for %O ₂ /Gas flow	PP1	hit %O ₂	O ₂ /GAS=PP1
6	(Optional) Enter %HCl/Gas for dry oxidation	PP2	hit %HCl	HCL=PP2
7	(Optional) Enter background doping concentration: Nd-Na(cm ⁻³)	Nl	hit DOPING	Nb=Nl
8	(Optional) Enter initial oxide thickness if non-zero	X1	hit TOX	TOX=X1
9	Enter time t1 (HH.MMSS) to obtain final oxide thickness X2(Angstroms)	t1	hit t->TOX	TIME=t1 TOX=X2
10	Enter final oxide thickness X2(Angstroms) to obtain oxidation time t1 (HH.MMSS)	X2	hit TOX->t	TOX=X2 TIME=t1

CHEMICAL PREDEPOSITION MODELING

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Initialize thermal cycle modeling (Dt=0)		hit CLEAR	CLEAR
2	Enter Dopant type (Boron, Phosphorous, Arsenic)		hit BORON hit PHOS hit ARSENIC	BORON PHOSPHOROUS ARSENIC
3	Enter temperature (degree C)	T1	hit TEMP	TEMP=T1
4	Enter surface concentration Nss (cm-3)	Nss	hit DOPING	Nb=Nss
5	Enter predeposition time t1 (HH.MMSS) to obtain final dose Q1 (cm-2)	t1	hit t->Q	TEMP=T1 TIME=t1 Q=Q1
6	Enter final dose Q1 (cm-2) to obtain pre-deposition time t1 (minutes)	Q1	hit Q->t	TEMP=T1 Q=Q1 TIME=t1

CHEMICAL DRIVE-IN MODELING

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Initialize thermal cycle modeling (Dt=0)		hit CLEAR	CLEAR
2	Enter Dopant type (Boron, Phosphorous, Arsenic)		hit BORON hit PHOS hit ARSENIC	BORON PHOSPHOROUS ARSENIC
3	Enter temperature T1 (degree C)	T1	hit TEMP	TEMP=T1
4	Enter ambient condition (Inert, Dry, Wet, steam)		hit INERT hit DRY hit WET hit STEAM	INERT AMBT. DRY OXID WET OXID STEAM OXID
5	(Optional) Enter oxide thickness X1(Angstroms)	X1	hit TOX	TOX=X1
6	(Optional) Enter silicon orientation nnn if oxidation ambient is chose	nnn	hit ORIENT	ORIENT=nnn
7	Enter initial dose Q1 (cm-2)	Q1	hit DOSE	Q=Q1
8	Declare chemical drive-in		hit NAT	UNIMPLANTED
9	Enter drive-in time (HH.MMSS) t1 to obtain surface concentration Nso (cm-3)	t1	hit t->Ns	TEMP=T1 TIME=t1 N(O)=Nso
10	Enter background doping concentration N1 (cm-3) for drive-in time calculation	N1	hit DOPING	Nb=N1
11	Declare chemical		hit NAT	UNIMPLANTED
12	Enter final junction depth X2 (um) to obtain drive-in time (HH.MMSS) and the surface concentration N2 (cm-3)	X2	hit Xj->t	TEMP=T1 XJ=X2 TIME=t1 N(O)=N2

SOURCE/DRAIN DIFFUSION MODELING

STEP	INSTRUCTION	INPUT	FUNCTION	DISPLAY
1	Initialize thermal cycle modeling (Dt=0)		hit CLEAR	CLEAR
2	Enter Dopant type (Boron, Arsenic)		hit BORON hit ARSENIC	BORON ARSENIC
3	Enter temperature (degree C)	T1	hit TEMP	TEMP=T1
4	Enter initial dose Q1 (cm-2)	Q1	hit DOSE	Q=Q1
5	Enter drive-in time t1 (HH.MMSS) to obtain junction depth (um), sheet resistance (ohms/square), and surface concentration (cm-3)	t1	hit t->SD	TEMP=T1 TIME=t1 XJ=X1 RS=Rsl CS=Csl
6	Enter final junction depth (um) X1 to obtain drive-in time (minutes) sheet resistance (ohms/square), and surface concentration (cm-3)	X1	hit SD->Xj	TEMP=T1 XJ=X1 TIME=t1 RS=Rsl CS=Csl

ION-IMPLANTED DIFFUSION MODELING

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Initialize thermal cycle modeling (Dt=0)		hit CLEAR	CLEAR
2	Enter Dopant type (Boron, Phosphorous, Arsenic)		hit BORON hit PHOS hit ARSENIC	BORON PHOSPHOROUS ARSENIC
3	Enter temperature T1 (degree C)	T1	hit TEMP	TEMP=T1
4	Enter Ambient condition (Inert,Dry,Wet,Steam)		hit INERT hit DRY hit WET hit STEAM	INERT AMBT. DRY OXID WET OXID STEAM OXID
5	(Optional) Enter initial oxide thickness X1 (Angstroms)	X1	hit TOX	TOX=X1
6	(Optional) Enter silicon orientation nnn if oxidation ambient is chosen	nnn	hit ORIENT	ORIENT=nnn
7	(Optional) Enter partial pressure for %O2/GAS flow if oxidation ambient is chosen	PPl	hit %O2	O2/GAS=PPl
8	(Optional) Enter %HCl/Gas flow if dry oxidation ambient is chosen with HCl as well	PP2	hit %HCl	HCL=PP2
9	Specify implantation condition by entering dose Q1 (cm ⁻²) and energy E1 (KeV) or Specify implantation condition by entering peak concentration Imax1 (cm ⁻³), range Rpl (Angstroms), straggle dRpl (Angstroms)	Q1 E1 Imax1 Rpl dRpl	hit DOSE hit ENERGY hit Imax hit Rp hit dRp	Q=Q1 EO=E1 IMAX-Imax1 RP=Rpl dRP=dRpl
10	Declare ion-implanted drive-in		hit IMPLANT	IMPLANTED
11	Enter drive-in time (HH.MMSS) t1 to obtain surface concentration Ns0 (cm ⁻³)	t1	hit t->Ns	TEMP=T1 TIME=t1 N(O)=Ns0

ION-IMPLANTED DIFFUSION MODELING

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
12	Enter background doping concentration N1 (cm-3) for drive-in calculation	N1	hit DOPING	Nb=N1
13	Declare ion-implanted drive-in		hit IMPLANT	IMPLANTED
14	Enter final junction depth X2 (um) to obtain drive-in time (HH.MMSS) and the surface concentration N2 (cm-3)	X2	hit Xj->t	TEMP=T1 XJ=X2 TIME=t1 N(0)=N2

GENERAL CONCENTRATION PROFILE TO GAUSSIAN PROFILE MODELING

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Perform Concentration profile modeling: Chemical drive-in or Ion-Implanted drive-in profiles			
2	Perform general concentration profile to gaussian profile conversion to obtain peak concentration I_{max1} (cm^{-3}), range R_{pl} (Angstroms), and straggle dR_{pl} (Angstroms)		XEQ ALPHA GAUSS ALPHA	GAUSSIAN $I_{MAX}=I_{max1}$ $RP=R_{pl}$ $dRP=dR_{pl}$

GAUSSIAN TO BOX PROFILE MODELING

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Enter background doping concentration N1 (cm-3)	N1	hit DOPING	Nb=N1
2	Enter Peak concentration Imax1 (cm-3)	Imax1	hit Imax	IMAX=Imax1
3	Enter range Rpl (Angstroms)	Rpl	hit Rp	RP=Rpl
4	Enter straggle dRpl (Angstroms)	dRpl	hit dRp	dRP=dRpl
5	Perform gaussian to box profile conversion to obtain box doping concentration height N2 (cm-3) and box width Xl (um)		hit BOX	BOX PROFILE NBX=N2 WBX=Xl

SILICON VACANCY CONCENTRATION MODELING

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Enter background doping concentration N1 (cm-3)	N1	hit DOPING	Nb=N1
2	Enter temperature T1 (degree C) to obtain silicon vacancy concentration N2 (cm-3)	T1	hit T->Siv	SIV=N2

IMPURITY DIFFUSION COEFFICIENT MODELING

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Enter dopnat type (Boron, Phosphorous, Arsenic)		hit BORON hit PHOS hit ARSENIC	BORON PHOSPHOROUS ARSENIC
2	Enter background dop- ing concentration N1 (cm-3)	N1	hit DOPING	Nb=N1
3	Enter ambient condi- tion (Inert, Dry, Wet, steam)		hit INERT hit DRY hit WET hit STEAM	INERT AMBT. DRY OXID WET OXID STEAM OXID
4	Perform oxidation calculation if oxida- tion ambient is chose			
5	Enter temperature T1 (degree C) to obtain diffusion coefficient DC1 (cm-^2/sec)	T1	hit t->Di	TEMP=T1 DX=DC1

INTRINSIC CARRIER CONCENTRATION MODELING

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Enter temperature T1 (degree C) to obtain the intrinsic carrier concentration N1 (cm-3)	T1	hit T--ni	TEMP=T1 NI=N1

CV PROFILE PARAMETER EXTRACTION MODELING

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Enter CV data to obtain background doping concentration N1 (cm-3), flatband capacitance C3 (pF), and gate oxide X1 (Angstroms)		hit CV-DATA	AREA(CM+2)?
2	Enter area of test capacitor in square centimeters A1	A1	hit R/S	CMAX (PF)?
3	Enter maximum capacitance C1 (pF)	C1	hit R/S	CMIN (PF)?
4	Enter minimum capacitance	C2	hit R/S	CV MEASURE TOX=X1 NB=N1 CFB=C3

UNIMPLANTED N-IGFET VT PROFILE PARAMETER EXTRACTION MODELING

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Enter gate oxide thickness X2(Angstroms)	X2	hit TOX	TOX=X2
2	Declare unimplanted N-IGFET		hit NAT	UNIMPLANTED
3	Enter number of data points (Vth, Vsb) to obtain background doping concentration N1 (cm-3), flatband voltage Vf (V), and least squares fit correlation coefficient RCC1		hit Vt-DATA	POINTS?
4	Enter number of Vth, Vsb data points for calculation NN1	NN1	hit R/S	VTH, VSB?
5	Enter first value for threshold voltage VT1 corresponding to its back bias voltage VS1	VT1	hit ENTER	VT1
6	Enter first value for back bias voltage VS1 (V) corresponding to the previous threshold voltage value VT1	VS1	hit R/S	VTH, VSB?
7	User is prompted for further inputs until required number of inputs (NN1) are satisfied Repeat steps #5-6			UNIMPLANTED NB=N1 VFB=V1 R2=RCC1

IMPLANTED N-IGFET VT PROFILE PARAMETER EXTRACTION MODELING

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Enter gate oxide thickness X2(Angstroms)	X2	hit TOX	TOX=X2
2	Enter background doping concentration N1 (cm-3)	N1	hit DOPING	Nb=N1
3	Declare implanted N=IGFET		hit IMPLANT	IMPLANTED
4	Enter Vth, Vsb data to obtain box doping concentration height N2 (cm-3), box width X1 (um), flatband voltage V1 (V), critical back bias voltage V6 (V), and least squares fit correlation coefficient RCC1		hit Vt-DATA	VTH, VSB?
5	Enter first value for threshold voltage VT1 corresponding to its back bias voltage VS1	VT1	hit ENTER	VT1
6	Enter first value for back bias voltage VS1 (V) corresponding to the previous threshold voltage value VT1	VS1	hit R/S	VTH, VSB?
7	User is prompted for further inputs until required number of inputs are satisfied Repeat steps #5-6			IMPLANTED NBX=N2 WBX=X1 VFB=V1 VC=V6 R2=RCC1

UNIMPLANTED N-IGFET THRESHOLD VOLTAGE MODELING

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Enter background doping concentration N1 (cm-3)	N1	hit DOPING	$N_b=N1$
2	Enter Gate oxide thickness X2(Angstroms)	X2	hit TOX	$TOX=X2$
3	Enter flatband voltage V1 (V)	V1	hit Vfb	$V_{FB}=V1$
4	Declare unimplanted N-IGFET		hit NAT	UNIMPLANTED
5	Enter substrate bias V2 (V) to obtain threshold voltage V3 (V)	V2	hit $V_{sb} \rightarrow V_{th}$	$V_{SB}=V2$ $V_{TH}=V3$

IMPLANTED N-IGFET THRESHOLD VOLTAGE MODELING

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Enter background doping concentration N1 (cm-3)	N1	hit DOPING	Nb=N1
2	Enter Gate oxide thickness X2(Angstroms)	X2	hit TOX	TOX=X2
3	Enter flatband voltage V1 (V)	V1	hit Vfb	VFB=V1
4	Enter box doping concentration height N2 (cm-3)	N2	hit Nbx	NBX=N2
5	Enter box width X3 (um)	X3	hit Wbx	WBX=X3
6	Declare implanted N=IGFET		hit IMPLANT	IMPLANTED
7	Enter substrate bias V2 (V) to obtain threshold voltage V3 (V)	V2	hit Vsb->Vth	VSB=V2 VTH=V3

IMPLANTED N-IGFET THRESHOLD VOLTAGE SHIFT MODELING

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Enter background doping concentration N1 (cm-3)	N1	hit DOPING	Nb=N1
2	Enter Gate oxide thickness X2(Angstroms)	X2	hit TOX	TOX=X2
3	Enter Peak concentration Imax1 (cm-3)	Imax1	hit Imax	IMAX=Imax1
4	Enter range Rpl (Angstroms)	Rpl	hit Rp	RP=Rpl
5	Enter straggle dRpl (Angstroms)	dRpl	hit dRp	dRP=dRpl
6	Enter inversion charge density N2(cm-2) (typical N2=1E14)	N2	hit Ninv	NINV=N2
7	Enter substrate bias V2 (V) to obtain threshold voltage shift V4 (V)	V2	XEQ ALPHA dVT ALPHA	VSB=V2 dVT=V4

IGFET CURRENT MODELING

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Enter threshold voltage V3 (V)	V3	hit Vth	VTH=V3
2	Enter gate to source voltage V5 (V)	V5	hit Vgs	VGS=V5
3	Enter Gate oxide thickness X2(Angstroms)	X2	hit TOX	TOX=X2
4	Enter mobility M1 ($\text{cm}^2/\text{V}\cdot\text{sec}$)	M1	hit MOBILITY	U=M1
5	Enter channel W/L dimensions WL1	WL1	hit W/L	W/L=WL1
6	Enter drain to source voltage V6 (V) to obtain drain to source current ID1 (amperes)	V6	hit Vds->Ids	VDS=V6 IDS=ID1

UNIMPLANTED N-IGFET SUBTHRESHOLD MODELING

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Enter Gate oxide thickness X2(Angstroms)	X2	hit TOX	TOX=X2
2	Enter background doping concentration N1 (cm-3)	N1	hit DOPING	Nb=N1
3	Enter substrate bias voltage V2 (V)	V2	hit Vsb	VSB=V2
4	Declare unimplanted N=IGFET		hit NAT	UNIMPLANTED
5	Enter inversion charge density N2 (cm-2) to obtain the gate to source voltage (without flatband voltage)V5 (V)	N2	hit $N_v \rightarrow V_{gs}$	$N_{INV}=N_2$ $V_{GS}=V_5$

IMPLANTED N-IGFET SUBTHRESHOLD MODELING

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Enter Gate oxide thickness X2(Angstroms)	X2	hit TOX	TOX=X2
2	Enter background doping concentration N1 (cm^{-3})	N1	hit DOPING	NB=N1
3	Enter substrate bias voltage V2 (V)	V2	hit VSB	VSB=V2
4	Enter Peak concentration Imax1 (cm^{-3})	Imax1	hit Imax	IMAX=Imax1
5	Enter range Rpl (Angstroms)	Rpl	hit Rp	RP=Rpl
6	Enter straggle dRpl (Angstroms)	dRpl	hit dRp	dRP=dRPl
7	Declare implanted N-IGFET		hit IMPLANT	IMPLANTED
8	Enter inversion charge density N2(cm^{-2}) to obtain the gate to source voltage (without flatband voltage) V5 (V)	N2	hit $N_v \rightarrow V_{gs}$	NINV=N2 VGS=V5

PLOTTING INSTRUCTIONS

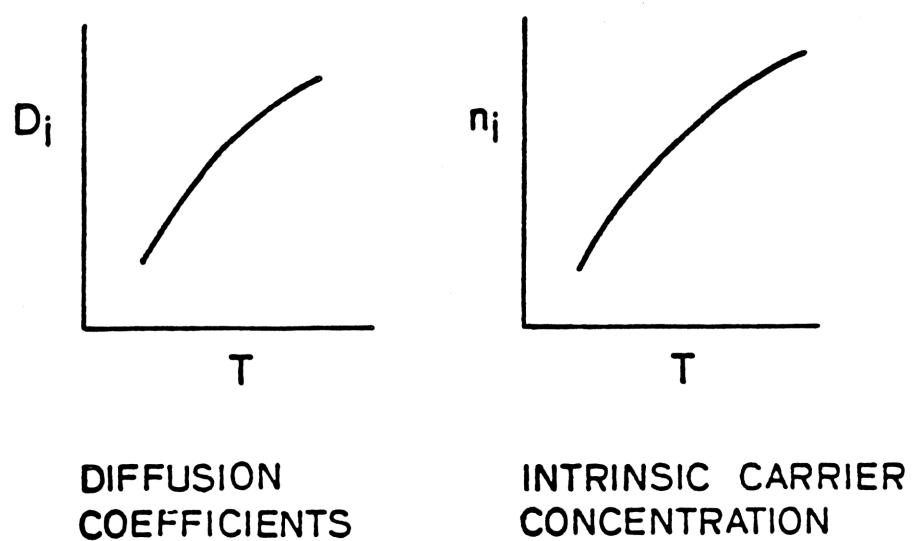
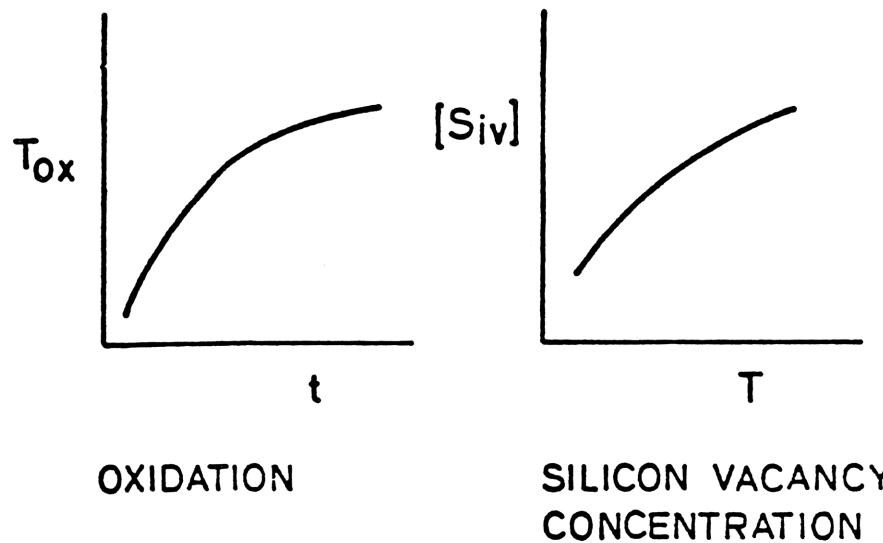
STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Connect printer to calculator			
2	Perform desired calculation for plotting			
3	Specify axis information for plot limits		hit PLOT	NAME?
4	Enter name for desired calculation: Name0 Ids (Vds)--IDS Vth (Vsb)--VTH Tox (t)--OXIDE N (x)--XN Vg (Ninv)--VGNV Siv (T)--SVT Di (T)--TDF ni (T)--TNI	Name0	hit R/S	YMIN?
5	Enter minimum y-value for desired calculation Outputs Ids(Vds)--Ids (amperes) Vth(Vsb)--Vth (V) Tox(t)--Tox (Angstroms) N(x)--Log (Nx) Vg(Ninv)--Vgs (V) Siv(T)--Log (Siv) Di (T)--Log (Di) ni (T)--Log (ni)	Yminl	hit R/S	YMAX?
6	Enter maximum y-value for desired calculation	Ymaxl	hit R/S	AXIS?
7	Enter x-axis intersection with y-axis	Xl	hit R/S	X MIN?
8	Enter minumum x-value for desired calculation	Xminl	hit R/S	X MAX?

CONTINUED ON NEXT PAGE

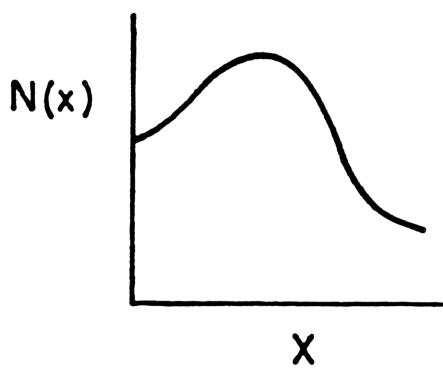
PLOTTING INSTRUCTIONS ***CONTINUATION***

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
9	Enter maximum x-value for desired calculation Inputs Ids (Vds)--Vds (V) Vth (Vsb)--Vsb (V) Tox (t)--time (minutes) N (x)--x (um) Vg (Ninv)--Log (Ninv) Siv (T)--T (degree C) Di (T)--T (degree C) ni (T)--T (degree C)	Xmax1	hit R/S	X INC?
10	Enter increment for x-axis to begin plotting procedure	Xincl	hit R/S	

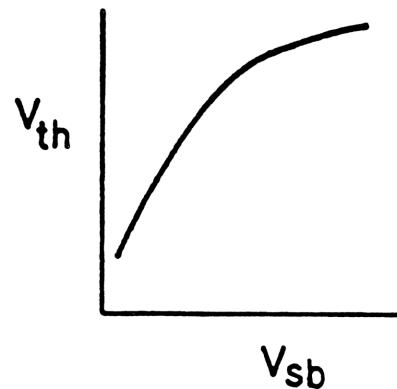
PLOTTING CAPABILITY



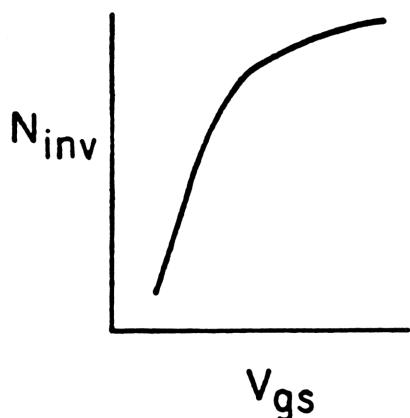
PLOTTING CAPABILITY



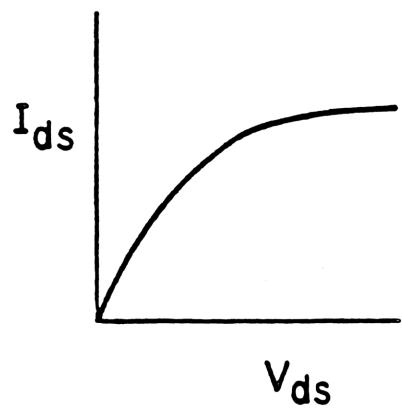
CONCENTRATION
PROFILES



THRESHOLD
VOLTAGE

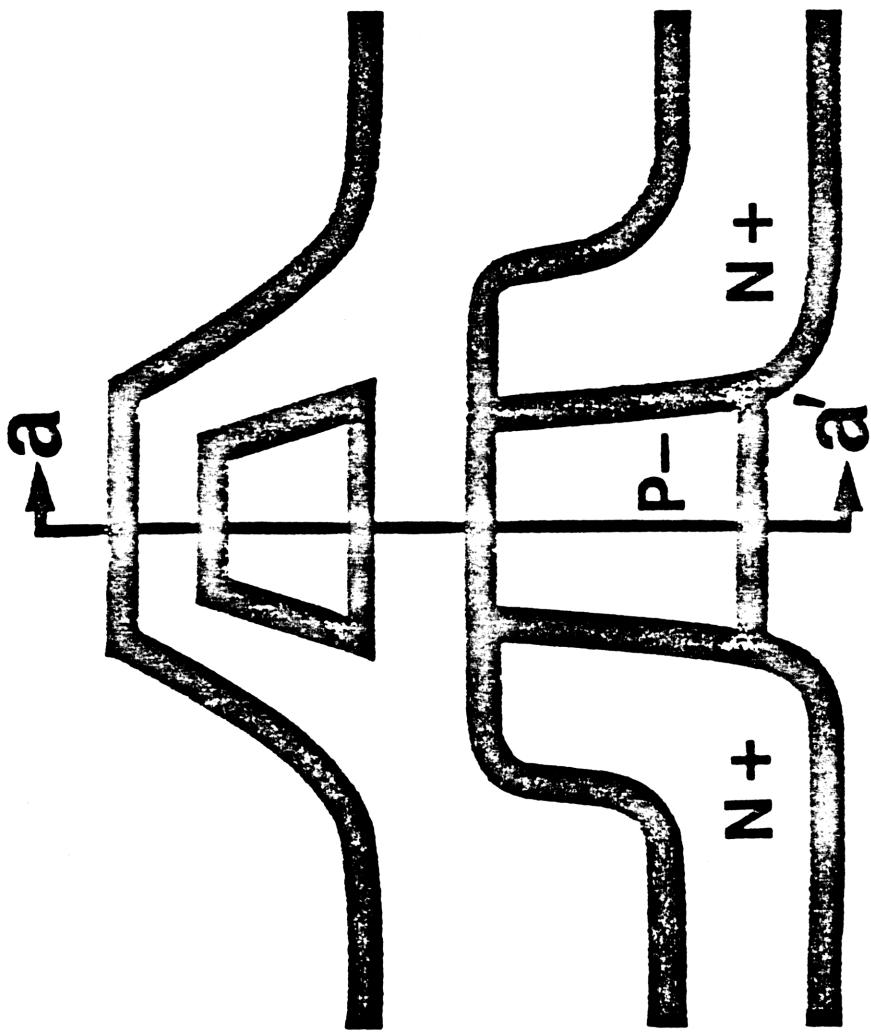


SUBTHRESHOLD
BEHAVIOR

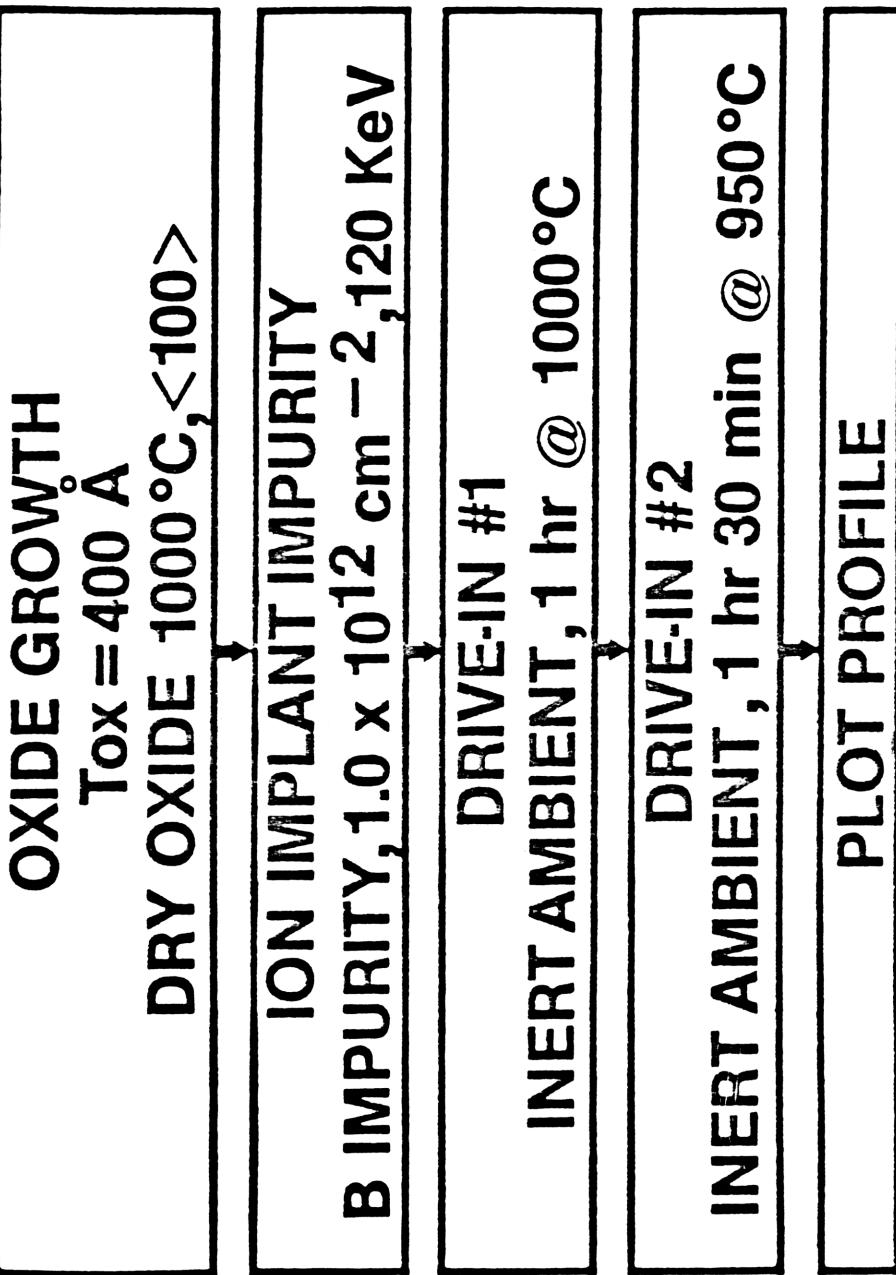


IGFET CURRENT

IGFET PROFILE EXAMPLE



IGFET PROFILE EXAMPLE



IGFET PROFILE EXAMPLE

STEP	INSTRUCTIONS	INPUT	FUNCTION	DISPLAY
1	Clear oxide register		hit CLEAR	CLEAR
2	Select dry oxidation ambient		hit DRY	DRY OXID
3	Enter 1000 ⁰ C as temperature	1000	hit TEMP	TEMP=1000.0 C
4	Enter (100) Si orientation	100	hit ORIENT	ORIENT=(100)
5	Enter final oxide thickness of 400 A to compute time	400	hit TOX→t	TOX=400 A TIME=0.3332
6	Enter boron dopant type		hit BORON	BORON
7	Enter dose of 1.0E12 cm-2	1.0E12	hit DOSE	Q=1.000E12
8	Enter energy of 120 KeV	120	hit ENERGY	E0=120 KeV
9	Specify inert ambient		hit INERT	INERT AMBT.
10	Declare ion-implanted drive-in		hit IMPLANT	IMPLANTED
11	Enter 1.0 hr as the drive-in time for Drive-in #1 to compute the surface concentration	1.0	hit t→Ns	TEMP=1000 C TIME=60 MIN N(0)=2.459E18
12	Enter distance of .6um from surface to compute N(X)	0.6	hit X→Nx	X=0.600 UM N(X)=3.760E18
13	Enter impurity concentration of 5E14 to compute X	5E14	hit Nx→X	N(X)=5.000E18 X=0.708 UM
14	Enter 950 ⁰ C as new temperature	950	hit TEMP	TEMP=950.0 C
15	Declare ion-implanted drive-in		hit IMPLANT	IMPLANTED
16	Enter 1 hr 30 min as the next drive-in time to compute the surface concentration	1.30	hit t→Ns	TEMP=950 C TIME=90 MIN N(0)=4.285E18
17	Initiate plot for N(X)		hit PLOT	NAME ?
18	Enter "XN" as plot name	XN	hit R/S	Y MIN ?
19	Enter 14 for Ymin	14	hit R/S	Y MAX ?
20	Enter 17 for Ymax	17	hit R/S	AXIS ?
21	Enter 14 for x-axis intersect	14	hit R/S	X MIN ?
22	Enter 0um for Xmin	0.0	hit R/S	X MAX ?
23	Enter 0.8um for Xmax	0.8	hit R/S	X INC ?
24	Enter 0.1um as X-increment	0.1	hit R/S	

KEY SUMMARY

ARSENIC Used to specify arsenic as the type of dopant atom.
BORON Used to specify boron as the type of dopant atom.
BOX Used to calculate the box height (Nb_x) and width (Wb_x) for an ion-implanted enhancement-mode IGFET.
CLEAR Used to clear the oxide and Dt register contents.
CV-DATA Used to calculate Nb (cm⁻³), TOX (Å), and C_{fb} (pF) for a test capacitor given C_{max} (pF), C_{min}(pF), and capacitor area in (cm⁻²).
DOPING Enter/View Nd-Na or Nb in cm⁻³.
DOSE Enter/View dose in cm⁻².
dRp Enter/View projected straggle in angstroms.
DRY Used to specify a dry oxidation ambient condition.
ENERGY Enter/View energy in KeV for a given implant species.
ZHC1 Enter/View the percent HCl used for dry oxidation.
Imax Enter/View the gaussian peak concentration in cm⁻³.
IMPLANT Used to specify an implanted IGFET or implant conditions.
INERT Used to specify an inert ambient condition.
INIT Places default values for process conditions into the appropriate register locations.
MOBILITY Enter/View mobility in cm²/volt*sec.
NAT Used to specify an unimplanted IGFET or chemical predep or drive-in conditions.
Nb_x Enter/View box profile height in cm⁻³.
Ninv Enter/View inversion charge density in cm⁻³.
Nx>X Enter the concentration in cm⁻³ to obtain the distance from the silicon-silica interface in um.
Nv>Vgs Enter the inversion charge density in cm⁻³ to obtain the gate to source voltage in volts for an IGFET.
ORIENT Enter/View the silicon substrate orientation (100,111).
Z02 Enter/View the percent of O₂/GAS flow used for oxidation conditions.
PHOS Used to specify phosphorous as the type of dopant atom.
PLOT Used with the 82143A perpherial printer to produce plots for N(X)-"N"; V_{th}(V_{sb})-"VTH"; TOX(t)-"OXIDE"; S_{iv}(T)-"SVT"; Di(T)-"TDF"; n_i(T)-"TNI"; I_{ds}(V_{ds})-"IDS"; and V_{gs}(Ninv)-"VGNV".
Q>t Enter the dose in cm⁻² with the time in HH.MMSS format displayed for the chemical predeposition.
Rp Enter/View the projected range in angstroms.
STEAM Used to specify a steam oxidation ambient condition.
T>Di Enter the temperature in °C to obtain the diffusion coefficient in cm²/volt*sec.
TEMP Enter/View temperature in °C.
T>n_i Enter the temperature in °C to obtain the intrinsic carrier concentration in cm⁻³.
TOX Enter/View oxide thickness in angstroms.
TOX>t Enter oxide thickness in agnstoms to obtain the time in HH.MMSS format.
t>Ns Enter the time in HH.MMSS format to obtain the surface concentration in cm⁻³.
t>Q Enter the time in HH.MMSS format to obtain charge in cm⁻² for the chemical predeposition.
t>TOX Enter the time in HH.MMSS format to obtain the oxide thickness in angstroms.

t>SD Enter the time in HH.MMSS format to obtain Xj in um,Rs in ohms per square, and surface concentration in cm-3 for a source/drain diffusion (inert ambient conditions only).
T>Siv Enter temperature in °C to obtain the total silicon vacancy concentration in cm-3.
Vds Enter/View the drain to source voltage in volts.
Vds>Ids Enter Vds in volts to obtain the drain to source current for an enhancement-mode IGFET.
Vfb Enter/View the flatband voltage in volts.
Vgs Enter/View the gate to source voltage in volts.
Vsb Enter/View the source to bulk voltage in volts.
Vsb>Vth Enter the source to bulk voltage in volts to obtain the threshold voltage in volts.
Vt-DATA User is prompted for (Vth,Vsb) to determine the curve-fitted profile parameters for the Vsb Vth key.
Vth Enter/View the threshold voltage in volts.
Wbx Enter/View the box profile width in um.
WET Used to specify a wet oxidation ambient condition.
W/L Enter/View the width to lenght aspect ratio for an IGFET.
X>Nx Enter the distance from the silicon-silica interface in um to obtain the concentration in cm-3.
Xj>SD Enter the junction depth in um to obtain the time in the HH.MMSS format for high dose drive-in (source/drain) diffusions (inert ambient conditions only).
Xj>t Enter the junction depth in um to obtain the time in the HH.MMSS format for low dose drive-in diffusions.

BUILT-IN FUNCTIONS

dVT Calculates the threshold shift for an implanted IGFET assuming a guassian concentration profile.
EF Calculates the error function (erf) value for the input in the X-Register.
IXQ Calculates the charge for a gaussian concentration profile given Rp, dRp,Imax entered via the keyboard.
PRPLOTP Programmable version of PRPLOT (see printer owner's manual).
RNG Calculates the range data (Rp,dRp) for a gaussian profile given dopant type and energy entered via the keyboard.
IMP Calculates Imax,Rp,dRp for a guassian profile given dopant type and dose,energy entered via the keyboard.

REGISTER ALLOCATION

REGISTER	CONTENTS	REGISTER	CONTENTS	REGISTER	CONTENTS
00	SIGx,Cmax	34	C1 (wet)	68	Beta
01	SIGx2,Cmin	35	E1 (wet)	69	"OEDn"
02	SIGy,Na*	36	C2 (wet)	70	Ninv
03	SIGy2,Cfb	37	E2 (wet)	71	Eg(eV)
04	SIGsy,AREA	38	x0 (wet)	72	n (cm-3)
05	n	39	C1 (steam)	73	Xj (um)
06	r2	40	E1 (steam)	74	Cs (cm-3)
07	mi	41	C2 (steam)	75	Rs (ohm/sq)
08	alpha	42	E2 (steam)	76	h (elect.)
09	al,b	43	x0 (steam)	77	N(x)
10	a0,Wbx*	44	B (cm2/sec)	78	x*
11	points	45	B/A (cm/sec)	79	xi,scratch
12	T(K)	46	A (cm)	80	scratch
13	Q(cm-2)	47	Tau (sec)	81	SIG(x)
14	t(sec)	48	1.68	82	segreg. coeff.
15	Dt (cm)	49	m0	83	A1
16	Rp-Tox (cm)	50	m1	84	A2
17	dRp (cm)	51	Vgs	85	A3
18	Tox (cm)	52	Deltai	86	x
19	Xox (cm)	53	X2,Deltau,cntr	87	t*
20	ni (cm-3)	54	psii,psi	88	psii*
21	D (cm2/sec)	55	psiu,psi*	89	psiu*
22	E0 (KeV)	56	Vcsb,xi-1	90	x1,delvth
23	Imax (cm-3)	57	a	91	m
24	r	58	Vsb	92	F(W)
25	ZHCl	59	Vth	93	W
26	Nd-Na,Nb	60	Vfb	94	F(X1)
27	B=-1,P=0,As=1	61	Wbx (cm)	95	F(X2),Ids
28	GAMMA	62	Nbx (cm-3)	96	F(X3),W/L
29	C1 (dry)	63	Dx=-1,Wx=0,Sx=1	97	Lb (cm)
30	E1 (dry)	64	O2/GAS	98	u (cm2/v*sec)
31	C2 (dry)	65	A (OAD), Y/X	99	Vds
32	E2 (dry)	66	(Siv)t		
33	x0 (dry)	67	(Siv)i,(Siv)t		

FLAG ALLOCATION

FLAG	1	0
00	IMPLANT	NAT/CHEMICAL
01	OXID AMBIENT	INERT AMBIENT
02	(100)	(111)
03	ENTER: Rp,dRp,Imax	ENTER: Q,E0
04	S/D DIFFUSION	LOW DOSE DIFFUSION
05	CHEMICAL PREDEP	CHEMCIAL DRIVE-IN
06	O2/GAS#1	O2/GAS=1
07	ZHCl#0	ZHCl=0
08	HEAVILY DOPED OXID	LIGHTLY DOPED OXID
09	MULTIPLE THERMAL CYCLES	NO PREVIOUS CYCLES
10	NO AVIEW	AVIEW

PRIDE MODELING EQUATIONS

I. PROCESS MODELING

A. OXIDATION:

OXIDE GROWTH EQUATIONS
DEFAULT OXIDATION COEFFICIENT VALUES
HCl OXIDATION MODIFICATION FOR DRY OXIDATION
HEAVILY-DOPED OXIDATION

B. DIFFUSION COEFFICIENTS:

INERT AMBIENT CONDITIONS
OXIDATION ENHANCED DIFFUSION

C. CHEMICAL DEPOSITION PROFILES

CHEMICAL PREDEPOSITION PROFILE
CHEMICAL DRIVE-IN PROFILE

D. ION-IMPLANTATION PROFILES:

INITIAL PROFILE DEFINITION
RANGE COEFFICIENTS
LOW-DOSE INERT AMBIENT DRIVE-IN PROFILE
LOW-DOSE OXIDIZING AMBIENT DRIVE-IN PROFILE
HIGH-DOSE INERT AMBIENT DRIVE-IN PROFILES
ARSENIC IMPURITY PROFILES
BORON IMPURITY PROFILES

E. OPTIMIZATION FOR PROFILE JUNCTION DEPTH

II. DEVICE MODELING

A. THRESHOLD SHIFT CALCULATION

B. INVERSION CHARGE CALCULATION

C. GAUSSIAN TO BOX PROFILE DETERMINATION

D. THRESHOLD VOLTAGE CALCULATION

UNIMPLANTED IGFET

IMPLANTED IGFET

E. IGFET CURRENT CALCULATION

III. PROFILE PARAMETER EXTRACTION ROUTINES

A. CV DATA PROFILE PARAMETERS

B. UNIMPLANTED IGFET V_{th} PROFILE PARAMETERS

C. IMPLANTED IGFET V_{th} PROFILE PARAMETERS

PROCESS MODELING: OXIDATION

OXIDE GROWTH EQUATIONS:

$$B = C1 \cdot P_{O_2} \cdot \exp(-E1/kT)$$

$$B/A = C2 \cdot P_{O_2} \cdot \exp(-E2/kT)$$

$$TOX = A/2 * (\sqrt{4B(t+\tau)/A^2 + 1} - 1)$$

$$t = A^2/4B * ((2TOX/A+1)^2 - 1) - \tau$$

$$\tau = x_i * (x_i + A)/B$$

DEFAULT OXIDATION COEFFICIENT VALUES:

	<u>C1(cm²/sec)</u>	<u>*C2(cm/sec)</u>	<u>E1(eV)</u>	<u>E2(eV)</u>
DRY	2.144E-9	0.173	1.230	2.000
WET	5.940E-10	2.490	0.710	2.000
STEAM	1.070E-9	4.530	0.780	2.050

*values for (111) Orientation where $C2(100)=C2(111)/1.680$

*HCl OXIDATION MODIFICATION FOR DRY OXIDATION:

$$\tau' = \tau/C3$$

$$(B/A)' = C4 * (B/A)$$

$$B' = B * C5 * \exp(C6 * \% HCl)$$

<u>TEMP(°C)</u>	<u>C3(100)</u>	<u>C3(111)</u>	<u>C4(100)</u>	<u>C4(111)</u>	<u>C5</u>	<u>C6</u>
900.00	4.00	3.00	2.0800	1.7798	1.0266	0.0676
1000.0	1.75	1.75	1.6351	1.3064	1.6380	0.0508
1100.0	2.25	2.25	2.1860	2.1064	1.3067	0.0471

*The above coefficients were fitted for HCl greater than one percent

HEAVILY-DOPED OXIDATION:

$$E_g = E_{g0} - \beta(\tau^2 / \tau + 636)$$

$$E_{g0} = 1.17 \text{ eV} \quad \beta = 4.73 \times 10^{-4} \text{ eV/}^\circ\text{K}$$

$$n = .5 \left[((N_d - N_a)^2 + 4n_i^2)^{1/2} + N_d - N_a \right]$$

$$n_i = (3.9 \times 10^{16} \text{ cm}^{-3}) T^{3/2} \exp(-0.605 \text{ eV}/kT)$$

$$B/A = \left(\frac{B}{A}\right)^i \left[1 + 2.6 \times 10^3 \exp\left(-\frac{1.1 \text{eV}}{kT}\right) \left\{ \frac{[V_T]}{[V_T]^i} - 1 \right\} \right]$$

$$[V_T] = V^0 \left\{ 1 + \frac{V^-}{V^0} + \frac{V^=}{V^0} + \frac{V^+}{V^0} \right\}$$

$$V^-/V^0 = \left(\frac{n}{n_i} \right) \exp \left(\frac{.44 - .5E_g}{kT} \right)$$

$$V^=/V^0 = \left(\frac{n}{n_i} \right)^2 \exp \left(\frac{.55 - E_g}{kT} \right)$$

$$V^+/V^0 = \left(\frac{n_i}{n} \right) \exp \left(\frac{.13 - .5E_g}{kT} \right)$$

$$V^0 = \left(5 \times 10^{22} \text{ cm}^{-3} \right) \exp \left(-3.0162 \times 10^4 / T \right)$$

PROCESS MODELING: DIFFUSION COEFFICIENTS

INERT AMBIENT CONDITIONS:

$$h = h + \left\{ (N_d - N_a) / 2n_i \right\} \left[((N_d - N_a) / 2n_i)^2 + 1 \right]^{-\frac{1}{2}}$$

$$D_{AS} = .066 h e^{-\frac{3.44 \text{eV}}{kT}} + 24 \left(\frac{n}{n_i} \right) e^{-\frac{4.05 \text{eV}}{kT}}$$

$$D_B = .037 h e^{-\frac{3.46 \text{eV}}{kT}} + \left(\frac{n_i}{n} \right) .72 e^{-\frac{3.46 \text{eV}}{kT}}$$

$$D_P = h \left\{ 3.85 e^{-\frac{3.66 \text{eV}}{kT}} + \left(\frac{n}{n_i} \right) 4.44 e^{-\frac{4 \text{eV}}{kT}} + \left(\frac{n}{n_i} \right)^2 44.2 e^{-\frac{4.37 \text{eV}}{kT}} \right\}$$

OXIDATION ENHANCED DIFFUSION:

OED0: SUPREM VERSION

$$D_B^* = \left\{ 1 + \hat{\beta} t^{-0.2} \exp\left(\frac{2.0882 \times 10^4}{T}\right) \right\} D_3$$

$$\hat{\beta} = \begin{cases} 7.2 \times 10^{-7} & \langle 100 \rangle \\ 3.3 \times 10^{-7} & \langle 111 \rangle \end{cases}$$

$$D_{As}^* = D_{As}$$

$$D_p^* = \begin{cases} 1.8 D_p & (\text{DRY}) \\ 3.3 D_p & (\text{WET}) \end{cases}$$

OED1: PLESSEY VERSION

$$D_I^* = D_I + \Delta D_I$$

$$\Delta D_B = \begin{cases} 4.1 \times 10^{-5} \exp(-2.34/kT) & \langle 100 \rangle \text{ DRY} \\ 1.5 \times 10^{-5} \exp(-2.30/kT) & \langle 110 \rangle \text{ DRY} \\ 3.9 \times 10^{-6} \exp(-2.22/kT) & \langle 111 \rangle \text{ DRY} \\ 7.5 \times 10^{-3} \exp(-2.85/kT) & \langle 100 \rangle \text{ WET} \\ 1.6 \times 10^{-5} \exp(-2.28/kT) & \langle 111 \rangle \text{ WET} \end{cases}$$

$$\Delta D_p = 3.7 \times 10^{-5} \exp(-2.39/kT) \quad \langle 100 \rangle \text{ DRY}$$

$$\Delta D_{As} = 1.9 \times 10^{-6} \exp(-2.34/kT) \quad \langle 100 \rangle \text{ DRY}$$

PROCESS MODELING: CHEMICAL DEPOSITION PROFILES:

CHEMICAL PREDEPOSITION PROFILE:

$$N(x,t) = C_s \operatorname{erfc}\left(\frac{x}{\sqrt{4Dt}}\right)$$

$$Q = 2 \cdot \sqrt{\frac{Dt}{\pi}} \cdot C_s \quad t = \frac{\pi Q^2}{4DC_s^2}$$

$$\operatorname{erfc}(u) = 1 - \operatorname{erf}(u)$$

$$x = \sqrt{4Dt} \operatorname{erfc}^{-1} [N(x,t)/C_s]$$

$$\operatorname{erfc}^{-1}(u) = \sqrt{-\frac{\pi}{4} \ln[1 - (1 - \operatorname{erfc}(u))^2]}$$

CHEMICAL DRIVE-IN PROFILE:

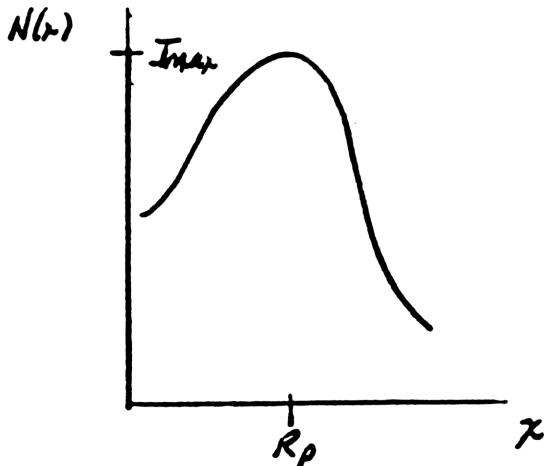
$$N(x,t) = \frac{Q}{\sqrt{\pi Dt}} \exp\left(-\frac{x^2}{4Dt}\right)$$

$$x = \sqrt{4Dt} \ln\left(\frac{Q}{N(x,t)} \cdot \frac{1}{\sqrt{\pi Dt}}\right)$$

$$t^{i+1} = \frac{x_i^2}{4D} \left(\ln \frac{Q}{N_B \sqrt{\pi D t^i}} \right)^{-1}$$

PROCESS MODELING: ION IMPLANTATION PROFILES

INITIAL PROFILE DEFINITION:



$$N(x) = I_{\max} \exp\left(-\frac{(x-R_p)^2}{2sR_p^2}\right)$$

$$x = \sqrt{2sR_p^2 \ln(I_{\max}/N(x))} + R_p$$

RANGE COEFFICIENTS:

$$\frac{E_0(\text{KeV})}{R_p, dR_p(\text{\AA})} \quad (R'_p = R_p - T_{\alpha})$$

BORON:

$$R_p = 52.2629 * E_0^{0.8909}$$

$$dR_p = 53.4216 * E_0^{0.5610}$$

PHOSPHOROUS:

$$R_p = 12.3612 * E_0^{1.000}$$

$$dR_p = 7.60460 * E_0^{0.8287}$$

ARSENIC:

$$R_p = 10.9590 * E_0^{0.8638}$$

$$dR_p = 3.03030 * E_0^{0.8038}$$

LOW-DOSE INERT AMBIENT DRIVE-IN PROFILE:

$$N(x) = N_i(x, t) \doteq \gamma [\sigma(x, t) + \sigma(-x, t)]$$

$$\gamma = \frac{I_{\max} sR_p}{\sqrt{8Dt + 4sR_p^2}}$$

$$r = \frac{sR_p^2}{2Dt}$$

$$I_{\max} = \sqrt{\frac{2}{\pi}} \cdot \frac{Q}{sR_p} \left(\frac{1}{1 + \exp(k_p/\sqrt{2sR_p})} \right)$$

$$t \approx \left\{ \frac{(x_j - R_p)^2}{4D \ln(2\gamma/N_B)} - \frac{sR_p^2}{2D} \right\}$$

$$\sigma(x, t) = \exp - \frac{(x - R_p)^2}{4(1+r)Dt} \left\{ 1 + \operatorname{erf} \left(\frac{R_p + rx}{\sqrt{8}R_p(2+r)^{\frac{1}{2}}} \right) \right\}$$

$$\operatorname{erf}(u) \approx \sqrt{1 - \exp \left(- \frac{4u^2}{\pi} \right)}$$

$$Dt = \sum_i D_i t_i$$

$$x \approx R_p + \sqrt{4(1+r)Dt \ln \frac{2\gamma}{N(x)}}$$

LOW-DOSE OXIDIZING AMBIENT DRIVE-IN PROFILE:

$$N(x, t) = N_1(x + \alpha T_{ox}, t) + N_2(x, t)$$

$$N_2(x, t) = \hat{A} \operatorname{erfc} \left(\frac{x + \alpha T_{ox}}{2\sqrt{Dt}} \right)$$

$$\hat{A} = (A_1 - A_2) / A_3 \quad \alpha = .44$$

$$A_1 = \frac{r}{(1+r)^{3/2}} \frac{R_p D I_{max}}{\sqrt{8}R_p \sqrt{Dt}} \left\{ \sigma(x + \alpha T_{ox}, t) - \sigma(-\alpha T_{ox}, t) \right\}$$

$$A_2 = \beta + \frac{\alpha T_{ox}}{2(1+r)t} \left\{ N_1(\alpha T_{ox}, t) \right\}$$

$$A_3 = \beta \operatorname{erfc} \frac{\alpha T_{ox}}{2\sqrt{Dt}} + \frac{D}{\pi \alpha^2} \exp \left(- \frac{\alpha^2 T_{ox}^2}{4Dt} \right)$$

$$t^{i+1} = \left\{ \frac{(x_j - .44 T_{ox}^i - R_p)^2}{4D^i \ln(2\gamma/N_A)} - \frac{sR_p^2}{2D^i} \right\}$$

$$\beta = \frac{1-\alpha m}{2m} \sqrt{\frac{B}{t + A^2/4B}}$$

$$M_3 = \begin{cases} 1126 \exp(-.91eV/kT) & \langle 111 \rangle \\ 2208 \exp(-.96eV/kT) & \langle 100 \rangle \end{cases}$$

$$M_p = 10$$

$$M_{As} = 10$$

HIGH-DOSE INERT AMBIENT DRIVE-IN PROFILES:

ARSENIC IMPURITY PROFILES:

$$N(x,t) = C_s \{1 - .874 - .45Y^2\}$$

$$Y = \chi \left(8C_s D_i^{-} t / n_i \right)^{-\frac{1}{2}}$$

$$D_i^{-} = 12 \exp(-4.05eV/kT)$$

$$\chi = \frac{- .87 + (.7569 - 1.8(N(x)/C_s - 1))^{1/2}}{.9} \left(\frac{8C_s D_i^{-} t}{n_i} \right)^{1/2}$$

$$C_s = .94 \left(Q^2 n_i / D_i t \right)^{1/3}$$

$$x_j = 2 \left(Q D_i t / n_i \right)^{1/3} \quad t = (n_i / D Q) \left(x_j / 2 \right)^3$$

$$R_s = \frac{1.7 \times 10^{10}}{Q^{2/3}} \left(\frac{n_i}{D_i t} \right)^{1/3}$$

BORON IMPURITY PROFILES:

$$N(x, t) = C_s \left\{ 1 - \left(x / x_j \right)^{2/3} \right\}$$

$$x_j = 2.5 Q / C_s$$

$$R_s = 2.78 \times 10^{12} / C_s x_j$$

$$x_j = 2.45 \left(C_s D_i t / n_i \right)^{1/2}$$

$$C_s = 1.014 \left(Q^2 n_i / D_i t \right)^{1/3}$$

$$D_i^+ = .72 \exp(-4.0135 \times 10^4 / T)$$

$$x = x_j \left(1 - N(x) / C_s \right)^{3/2}$$

$$x = \frac{2.5 Q}{C_s} \left\{ 1 - \frac{N(x)}{C_s} \right\}^{3/2}$$

$$t = \frac{n_i}{C_s D_i^+} \left(\frac{x_j^2}{6} \right)$$

PROCESS MODELING: CURVE FITTED PARAMETERS FOR ION IMPLANTATION PROFILES

LOW-DOSE INERT AMBIENT DRIVE-IN PROFILE:

$$U_1 = \frac{x - R_p}{\sqrt{4Dt(1+r)}} \quad U_2 = \frac{R_p + rx}{\Delta R_p \sqrt{2(1+r)}}$$

$$U_3 = \frac{-1(x - R_p)}{\sqrt{4Dt(1+r)}} \quad U_4 = \frac{R_p - rx}{\Delta R_p \sqrt{2(1+r)}}$$

$$g(u) = \frac{4u \exp(-4u^2/\pi)}{\pi \sqrt{1 - \exp(-4u^2/\pi)}}$$

$$P_4 = U_3 e^{-U_3^2} (1 + \operatorname{erf} U_4) - U_1 e^{-U_1^2} (1 + \operatorname{erf} U_2)$$

$$U_5 = e^{-U_1^2} g(U_2) - e^{-U_3^2} g(U_4)$$

Solve for the new range (R_p') by iteration using:

$$\frac{2P_4}{\pi} + U_5 = 0$$

Determine the new value for I_{max}' :

$$I_{max}' = \gamma \left\{ \sigma(R_p') + \sigma(-R_p') \right\}$$

Calculate the new value for the straggle ($\Delta R_p'$):

$$\Delta R_p' = \sqrt{4(1+r)Dt \ln \frac{2\gamma}{.60653 I_{max}'}} + (R_p - R_p')$$

PROFILE PARAMETER EXTRACTION ROUTINES

CV DATA PROFILE PARAMETERS:

$$T_{ox} = \epsilon_{ox} A / C_{max}$$

$$N_A^{i+1} = \frac{4KT\epsilon_{si}}{g^2} \left(\ln \frac{N_A^i}{n_i} \right) \left\{ T_{ox} \epsilon_{si} \left(\frac{C_{max}}{C_{min}} - 1 \right) \right\}^{-2}$$

$$C_{fb} = \left[1 + \left(\epsilon_{ox} / T_{ox} \epsilon_{si} \right) \left(K \tau \epsilon_{si} / N_A g^2 \right)^{1/2} \right]^{-1} \cdot C_{max}$$

UNIMPLANTED IGFET V_{th} PROFILE PARAMETERS:

PROCEDURE:

1. Assume the following functional form for V_{th}:

$$V_{th} = \alpha + \beta (V_{sb} + \varphi_{so})^{1/2}$$

2. Iterate using the above equation to solve for N_b until all of the following equations are mutually satisfied for the same value of N_b.

$$N_b = (\beta \epsilon_{ox} / T_{ox})^2 / 2g \epsilon_{si}$$

$$\varphi_{so} = 2KT \ln \frac{N_b}{n_i}$$

$$V_{fb} = \alpha - \varphi_{so}$$

IMPLANTED IGFET V_{th} PROFILE PARAMETERS:

PROCEDURE:

1. Note: There must be at least four values for V_{th} such that the channel depletion width lies within the ion-implanted region (V_{sb} < V_c).

2. Perform a least squares fit to the first three data points using:

$$V_{th} = \alpha_0 + \beta_0 (V_{sb} + .7)^{1/2}$$

3. For each additional (V_{th}, V_{sb}) input, compute the first order slope using the previous data values for (V_{th}, V_{sb}):

$$m = \frac{V_{th,i} - V_{th,i-1}}{(V_{sb,i} + .7)^{1/2} - (V_{sb,i-1} + .7)^{1/2}}$$

4. If the difference between m and B_0 is greater than 30% then the last values indicate the channel depletion width extends past the ion-implanted region. ($V_{sb} > V_c$)

$$\gamma \doteq \left| \frac{B_0 - m}{B_0} \right|$$

5. Perform a least squares fit for all data points ($i=0$ to $j-1$) that lie within the box region:

$$V_{TH} = \alpha + \beta(V_{sb} + \gamma)^{\frac{1}{2}}$$

$$N_{bx} = \beta^2 C_{ox}^2 / 2g\epsilon_s$$

6. Solve for V_{fb} :

$$V_{fb} = \alpha - Q_{so}$$

$$Q_{so} = \frac{2kT}{\gamma} \ln \frac{N_{bx}}{n_i}$$

7. Determine the value for the box profile width (W_{bx}) by using the two data points that lie outside the box ($i=j$ and $j+1$). Outside the box, V_{th} is given by:

$$V_{TH} = V_{fb} + Q_{so} + g(N_{bx} - N_b)W_{bx}/C_{ox} + \sqrt{2g\epsilon_s N_b} \left(V_{sb} + Q_{so} - g \frac{(N_{bx} - N_b)W_{bx}^2}{2\epsilon_s} \right)^{\frac{1}{2}}$$

8. For an initial guess for W_{bx} , assume V_{sbj} is the breakpoint voltage (V_c).

$$W_{bx} = \left(\frac{2\epsilon_s (V_{sbj} + \gamma)}{g N_{bx}} \right)^{\frac{1}{2}}$$

9. Use the last data point to observe charge conservation by determining the correct W_{bx} by iteration to match the data value to the first order equation:

$$W_{bx}^{(i+1)} = \frac{C_{ox}}{g(N_{bx} - N_b)} \left\{ V_{Th} - V_{fb} - Q_{so} - \sqrt{2g\epsilon_s N_b} \left(V_{sb(j+1)} + Q_{so} - g \frac{(N_{bx} - N_b)W_{bx}^{(i)} C_{ox}}{2\epsilon_s} \right)^{\frac{1}{2}} \right\}$$

10. Solve for the breakpoint voltage (V_c):

$$V_c = g \frac{N_{bx} W_{bx}^2}{2\epsilon_s} - \frac{2kT}{g} \ln \frac{N_{bx}}{n_i}$$

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II. DEVICE MODELING

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- D1. Wang, "Device Characteristics of Short-Channel and Narrow-Width MOSFETs," IEEE Trans. Electron Devices, 25, July 1978, pg 779.
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III. PROFILE PARAMETER EXTRACTION ROUTINES

- A1. Sze, Physics of Semiconductors.

KEY ASSIGNMENTS FOR ROM ID 21

TO	11
QT	-11
TN	12
TN*	-12
TSD	13
SDT	-13
XN	14
NX	-14
TTX	15
TXT	-15
T	21
VFB	-72
TX	22
VSB	-73
DS	23
VT	-74
EG	24
WBX	-61
WL	-81
DG	25
NBX	61
HC	-33
BR	-23
P	-24
RP	-21
AS	-25
dPP	-22
UU	81
IXV	-32
NVV	71
O2	-34
O	-35
INIT	-71
ET	-44
INT	32
BOX	-62
VTH	-63
NVG	-64
DX	33
VGS	-82
VDS	-83
IDS	-84
WX	34
NAT	-42
ENH	-43
PLOT	-41
SX	35
SVT	-52
TDF	-53
TNI	-54

BUILD FILE: SUPREM1

HEADER=PRIDE

11 bytes used
4069 bytes left

FILE=TX

52 bytes used
4017 bytes left

FILE=PLOT

*** WARNING: XROM 29,14
39 bytes used
3978 bytes left

FILE=PP

54 bytes used
3924 bytes left

FILE=dRP

56 bytes used
3868 bytes left

FILE=0

60 bytes used
3808 bytes left

FILE=WBX

55 bytes used
3753 bytes left

FILE=INIT

193 bytes used
3560 bytes left

FILE=TTY

208 bytes used
3352 bytes left

FILE=TOX

189 bytes used
3163 bytes left

FILE=HD

87 bytes used
3076 bytes left

FILE=HCL

*** WARNING: SHORT FORM GOTO
LABEL 6 OUT OF RANGE
*** WARNING: SHORT FORM GOTO
LABEL 4 OUT OF RANGE
*** WARNING: SHORT FORM GOTO
LABEL 6 OUT OF RANGE
224 bytes used
2852 bytes left

FILE=OED00

91 bytes used
2761 bytes left

FILE=OED1

*** WARNING: SHORT FORM GOTO
LABEL 1 OUT OF RANGE
*** WARNING: SHORT FORM GOTO
LABEL 2 OUT OF RANGE
*** WARNING: SHORT FORM GOTO
LABEL 2 OUT OF RANGE
*** WARNING: SHORT FORM GOTO
LABEL 2 OUT OF RANGE
205 bytes used
2556 bytes left

FILE=DS

761 bytes used
1795 bytes left

FILE=TDF

131 bytes used
1664 bytes left

266 bytes used
1398 bytes left

FILE=SDT
310 bytes used
1088 bytes left

FILE=TQ
162 bytes used
926 bytes left

FILE=RNG
162 bytes used
764 bytes left

FILE=DF
207 bytes used
557 bytes left

FILE=SEG
73 bytes used
484 bytes left

FILE=TN
161 bytes used
323 bytes left

FILE=KEYASN
323 bytes used
0 bytes left

BUILD FILE: SUPREM2

FILE=TN*
*** WARNING: SHORT FORM GOTO
LABEL 1 OUT OF RANGE
*** WARNING: SHORT FORM GOTO
LABEL 6 OUT OF RANGE
447 bytes used
3633 bytes left

FILE=TTX*
105 bytes used
3528 bytes left

FILE=BOX
204 bytes used
3324 bytes left

FILE=ROOT*
149 bytes used
3175 bytes left

FILE=T
73 bytes used
3102 bytes left

FILE=0XIDE
34 bytes used
3068 bytes left

FILE=EF
42 bytes used
3026 bytes left

FILE=PSII*
556 bytes used
2470 bytes left

FILE=FW
287 bytes used
2183 bytes left

FILE=NUG
330 bytes used
1953 bytes left

FILE=VTH
*** WARNING: SHORT FORM GOTO
LABEL 0 OUT OF RANGE
254 bytes used
1599 bytes left

FILE=UW
254 bytes used
1345 bytes left

FILE=XN
*** WARNING: SHORT FORM GOTO
LABEL 0 OUT OF RANGE
*** WARNING: SHORT FORM GOTO
LABEL 0 OUT OF RANGE
276 bytes used
1069 bytes left

FILE=CP
171 bytes used
898 bytes left

FILE=NX
*** WARNING: SHORT FORM GOTO
LABEL 0 OUT OF RANGE
*** WARNING: SHORT FORM GOTO
LABEL 0 OUT OF RANGE
*** WARNING: SHORT FORM GOTO
LABEL 0 OUT OF RANGE
305 bytes used
593 bytes left

FILE=BCL
263 bytes used
330 bytes left

FILE=VN
241 bytes used
89 bytes left

FILE=SUT
86 bytes used
3 bytes left

CHECKSUM FOR ROM ID 21 = 480

CHECKSUM FOR ROM ID 31 = 161
BUILD COMPLETED

18:17:32 AUGUST 6 1991

LOAD: SUPREM1
MEMORY: 1
SUPREM1 IN EMULATOR MEMORY 1

18:18:57 AUGUST 6 1991

LOAD: SUPREM2
MEMORY: 2
SUPREM2 IN EMULATOR MEMORY 2

CATALOG OF ROM ID 21

HEADER: PRIDE

RS
DF
DG
DS
DX
EG
ENH
ET
HC
HCL
HD
INIT
INT
NAT
NBX
NI
O
O2
OED0
OED1
P
PLOT
QT
RNG
RP
SDT
SEG
SV
SX
TDF
TN
TNI
TOX
TQ
TSD
TTX
TX
TXT
VFB
VGNV
VQ
VSB
VT
WBX
WX
dRP

CATALOG OF ROM ID 31

A0
ACL
BCL
BOX
BR
CP
CX
DELI*
DELU
DELVT
EF
FF
FP
FW
GM
IOS
IEF
IMP
IX
IXQ
IXV
LB
MQ
M0*
M1
M1*
NVG
NUV
NX
OXIDE
PF
PSII*
PSIU
R
ROOT*
SG
SVT
T
TN*
TTX*
UU
VDS
VGS
VT*
VTH
VW
WL
XN
dVT

01LBL "DS"
 FS?C 22 STO 13
 XEQ "YQ" SF 88 RTN

07LBL "YQ"
 "Q" SCI 3 ARCL 13
 AVIEW RTN

13LBL "EG"
 FS? 22 CF 83 FIX 22
 STO 22 SF 88 "EAT"
 FIX 8 ARCL 22 "EV"
 AVIEW RTN

25LBL "DG"
 FS?C 22 STO 26 CF 88
 SF 88 "Nb" ARCL 26 AVIEW RTN

35LBL "INT"
 CF 01 CF 22
 "INERT AMBT." AVIEW
 RTN

41LBL "DX"
 SF 01 -1 STO 63 CF 22
 "DRY OXID" AVIEW RTN

49LBL "WX"
 SF 01 0 STO 63 CF 22
 "WET OXID" AVIEW RTN

57LBL "SX"
 SF 01 1 STO 63 CF 22
 "STEAM OXID" AVIEW RTN

65LBL "P"
 0 STO 27 CF 12
 "PHOSPHOROUS" AVIEW
 RTN

72LBL "AS"
 1 STO 27 CF 22
 "ARSENIC" AVIEW RTN

79LBL "ET"
 CF 06 CF 07 CF 08
 CF 09 0 STO 19 STO 18
 STO 19 CF 22 "CLEAR"
 FC? 10 AVIEW RTN

93LBL "HC"
 FS? 22 STO 17 FIX 2
 FS?C 22 SF 01 "HCL"
 ARCL 25 "T" AVIEW
 RTN

104LBL "O2"
 FS?C 22 GTO 01 100
 ST* 64 GTO 02

ENTER / VIEW
 Q/cm⁻²
 VIEW Q
 (cm⁻²)

ENTER / VIEW
 E₀ (KeV)

ENTER / VIEW
 DOPING
 (cm⁻³)

"INERT" KEY

"DRY OXID" KEY

"WET OXID" KEY

"STEAM OXID" KEY

"PHOSPHOROUS" KEY

"ARSENIC" KEY

ENTER / VIEW
 % HCl/GAS

110LBL 81
 SF 06 STO 64

113LBL 92
 FIX 1 "O2/GAS"
 ARCL 64 "T" AVIEW
 .01 ST* 64 RTN

122LBL "VSB"
 FS?C 22 STO 58 FIX 3
 "VSB" ARCL 58 "T V"
 AVIEW RTN

131LBL "VT"
 FS?C 22 STO 59 FIX 3
 "VT" ARCL 59 "T V"
 AVIEW RTN

140LBL "VFB"
 FS?C 22 STO 60 FIX 3
 "VFB" ARCL 60 "T V"
 AVIEW RTN

149LBL "NBX"
 FS?C 22 STO 62 SCI 3
 "NBX" ARCL 62 AVIEW
 RTN

157LBL "NAT"
 CF 00 CF 22
 "UNIMPLANTED" AVIEW
 RTN

163LBL "ENH"
 SF 00 CF 22
 "IMPLANTED" AVIEW RTN

169LBL "NI"
 -7018.56 RCL 12 / E_{TX}
 3.9 E16 * ENTER[↑]
 RCL 12 ENTER[↑] 1.5 Y_{TX}
 * STO 20 CF 22 RTN

185LBL "SV"
 RCL 12 636 + 1/X
 ENTER[↑] RCL 12 X₁₂ *
 -4.73 E-4 * 1.17 +
 STO 71 -.5 * .44 +
 8.62 E-5 / RCL 12 /
 E_{TX} RCL 72 * RCL 20
 / 1 + STO 67 .55
 RCL 71 - 8.62 E-5 /
 RCL 12 / E_{TX} ENTER[↑]
 RCL 72 ENTER[↑] RCL 20
 / X₁₂ * ST+ 67 -.5
 RCL 71 * .13 +
 8.62 E-5 / RCL 12 /
 E_{TX} RCL 20 * RCL 72
 / ST+ 67 -38162
 RCL 12 / E_{TX} 5 E22 *
 ST* 67 CF 22 RTN

ENTER / VIEW
 % O₂ / GAS

ENTER / VIEW
 V_{sb} (V)

ENTER / VIEW
 V_{th} (V)

ENTER / VIEW
 V_{Fb} (V)

ENTER / VIEW
 Nb_x (cm⁻³)

"UNIMPLANTED
 (NAT)
 KEY"

"IMPLANTED"
 KEY

Ni (T)
 (cm⁻³)

Si (T)
 (cm⁻³)

COMPUTED
 SILICON
 VACANCY
 CONCENTRATION

LOW-DOSE OXIDIZING AMBIENT DRIVE-IN PROFILE:

$$U_1 = \frac{x + \alpha T_{ox} - R_p}{\sqrt{4Dt(1+r)}} \quad U_2 = \frac{R_p + r(x + \alpha T_{ox})}{\Delta R_p (2+2r)^{1/2}}$$

$$U_3 = \frac{-(x + \alpha T_{ox} + R_p)}{\sqrt{4Dt(1+r)}} \quad U_4 = \frac{R_p - r(x + \alpha T_{ox})}{\Delta R_p (2+2r)^{1/2}}$$

$$U_5 = \frac{x + \alpha T_{ox}}{2\sqrt{Dt}}$$

$$P_4 = \frac{2}{\pi r} \left\{ U_3 e^{-U_3^2} (1 + \exp(U_4)) - U_4 e^{-U_4^2} (1 + \exp(U_3)) \right\}$$

$$P_5 = g(U_2) \cdot e^{-U_1^2} - g(U_4) e^{-U_3^2}$$

$$P_6 = \frac{\pi \gamma}{4AU_5} \left(\frac{r}{1+r} \right)^{\frac{1}{2}} \left\{ 1 - \exp \left(- \frac{4U_5^2}{\pi} \right) \right\}$$

Solve for the new range (R_p') by iteration using:

$$x + \alpha T_{ox} - \sqrt{-\pi D t \ln[P_6(P_4 + P_5)]} = 0$$

Calculate the new value for the straggle ($\Delta R_p'$):

$$\Delta R_p' = \sqrt{4(1+r)Dt \ln \left(\frac{2\gamma}{0.60653 I_{max}'} \right)} + R_p - 44T_{ox} - R_p'$$

Calculate the new I_{max}' and effective charge (Q'):

$$Q' = \sqrt{2\pi} \cdot I_{max}' \cdot \Delta R_p'$$

$$I_{max}' = N(R_p')$$

The error function is approximated by the following expression:

$$\text{erf}(u) \approx \left\{ 1 - \exp\left(-\frac{u^2}{\pi}\right) \right\}^{\frac{1}{2}}$$

Assume that:

$$\beta = 40 \text{ V}^{-1}$$

$$E_{Si} = 1.0366 \times 10^{-12} \text{ F/cm}$$

$$C_{ox} = 3.4554 \times 10^{-13} \text{ F/cm}$$

3. Having solved for W , calculate βQ_{SI} :

$$\beta Q_{SI} = [W^2/2L_b^2 + m_i + 1 + \ln N_d/N_A(w)]$$

4. Iterate for βQ_{SU} :

$$\begin{aligned} \beta Q_{SU}^{i+1} &= \beta V_{SB} + 2 \ln \frac{N_d}{n_i} + \ln \left(\frac{(\beta g_{N,inv})^2}{a C_{ox}} \right)^{\frac{1}{2}}, \frac{2 \beta g_{N,inv} \Delta u^i}{a C_{ox}} \end{aligned}$$

$$\Delta u^i = (\beta Q_{SU}^i - 1)^{\frac{1}{2}}$$

5. Calculate the threshold shift in volts:

$$\beta \Delta V_T = \beta (Q_{SI} - Q_{SU}) + a (A_I - A_u)$$

DEVICE MODELING: INVERSION CHARGE CALCULATION

PROCEDURE:

1. Perform steps 1-3 (above) for an ion-implanted IGFET or step 4 for an unimplanted IGFET.
2. Calculate the V_{GS} needed to maintain the specified value for N_{inv} :

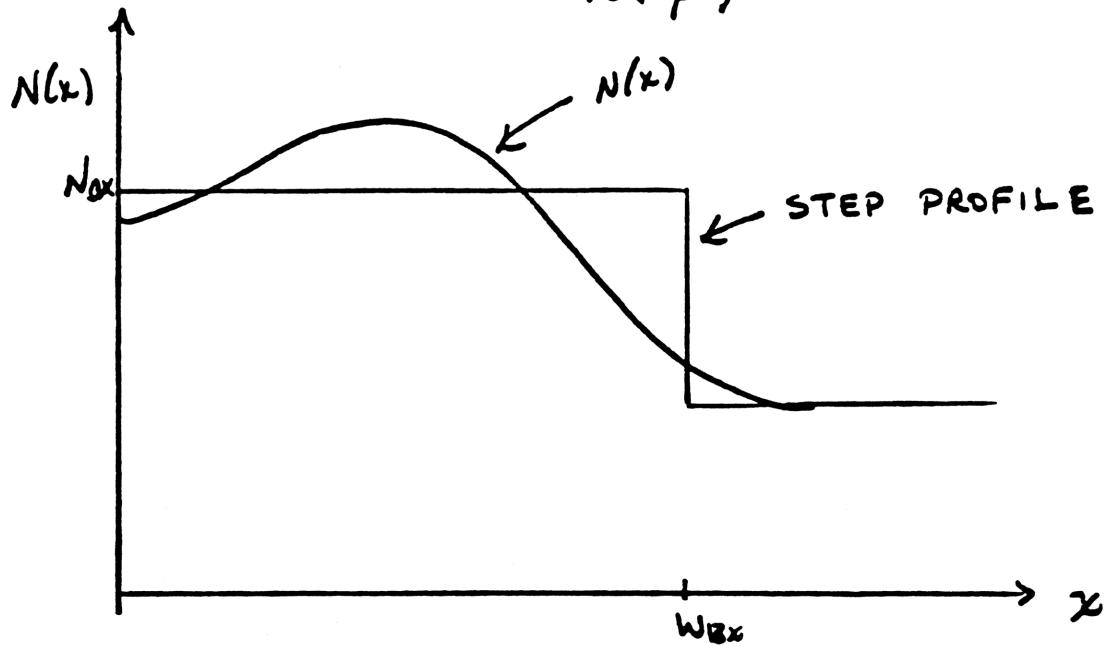
$$V_{GS} = \frac{g_{N,inv}}{C_{ox}} + Q_S + \frac{a \Delta}{\beta}$$

DEVICE MODELING: GAUSSIAN TO BOX PROFILE DETERMINATION

$$W_{bx} = \sqrt{2 \Delta R_p^2 \ln(I_{max}/N_0)} + R_p$$

$$N_{bx} = \frac{\pi}{2} \left(\frac{\Delta R_p I_{max} (\beta + \operatorname{erf} R_p / \sqrt{2 \Delta R_p})}{W_{bx}} \right) + N_0$$

$$\beta = \operatorname{erf} \left(\frac{R_p - R_p}{\sqrt{2 \Delta R_p}} \right)$$



DEVICE MODELING: THRESHOLD VOLTAGE CALCULATION

UNIMPLANTED IGFET:

$$V_{TH} = V_{FB} + \varphi_{SO} + \sqrt{2\gamma\epsilon_s N_S (V_{SB} + \varphi_{SO}) / Cox}$$

$$\varphi_{SO} = \frac{2kT}{\gamma} \ln \frac{N_S}{n_i}$$

IMPLANTED IGFET:

$$V_{TH} = \begin{cases} V_{FB} + \varphi_{SO} + \sqrt{2\gamma\epsilon_s N_{SX} (V_{SB} + \varphi_{SO}) / Cox} & V_{SB} < V_c \\ V_{FB} + \varphi_{SO} + g(N_{SA} - N_3) h_{SA} / Cox \\ + \sqrt{\frac{2\gamma\epsilon_s N_3}{Cox}} \left(V_{SB} + \varphi_{SO} - g \frac{(N_{SX} - N_3) h_{SX}^2}{2\epsilon_s} \right)^{\frac{1}{2}} & V_{SB} \geq V_c \end{cases}$$

$$V_c = g \frac{N_{SX} W_{SX}^2}{2\epsilon_s} - \varphi_{SO} \quad \varphi_{SO} = \frac{2kT}{\gamma} \ln \frac{N_{SX}}{n_i}$$

DEVICE MODELING: IGFET CURRENT CALCULATION

$$I_{DS} = \begin{cases} \mu \frac{CoxW}{L} (V_{GS} - V_{TH} - 5V_{OS}) V_{OS} & V_{OS} < V_{GS} - V_{TH} \\ \frac{\mu CoxW}{2L} (V_{GS} - V_{TH})^2 & V_{OS} \geq V_{GS} - V_{TH} \end{cases}$$

255•LBL "THI"
 STO 2 •TEMP= FIX 1
 ARCL 2 °F C° FC? 10
 AVIEW 273 + STO 12
 XEQ "NI" SCI 3 TONE 9
 "NI=" ARCL 20 FC? 10
 AVIEW CF 22 RCL 20
 LOG RTN END

01•LBL "DF"
 RCL 27 X<0? GTO 00
 X>0? GTO 01 -42459.4
 RCL 12 / E↑X 3.85 *
 STO 21 -46483.71
 RCL 12 / E↑X 4.44 *
 RCL 72 * RCL 20 /
 ST+ 21 -50696.06
 RCL 12 / E↑X 44.2 *
 ENTER↑ RCL 72 ENTER↑
 RCL 20 / X↑2 *
 ST+ 21 RCL 76 ST* 21
 GTO 02

42•LBL 00
 -40139.21 RCL 12 /
 E↑X .837 * RCL 76 *
 STO 21 -40139.21
 RCL 12 / E↑X .72 *
 RCL 20 * RCL 72 /
 ST+ 21 GTO 02

64•LBL 01
 -39907.19 RCL 12 /
 E↑X .866 * RCL 76 *
 STO 21 -46983.76
 RCL 12 / E↑X 24 *
 RCL 72 * RCL 20 /
 ST+ 21

85•LBL 02
 FS? 01 XEQ IHD 69
 RCL 21 RCL 14 *
 ST+ 15 CF 22 RTN END

01•LBL "HCL"
 1 RCL 25 X<=Y? GTO 06
 1173 STO Y RCL 12
 X=Y? GTO 01 1273
 STO Y RCL 12 X=Y?
 GTO 02 1373 STO Y
 RCL 12 X=Y? GTO 03
 GTO 04

22•LBL 01
 RCL 25 .0676 * E↑X
 1.0266 ST* 44 FS? 02
 GTO 05 3 ST/ 47
 1.7798 ST* 45 GTO 06

"T → n_i(T)"

KEY

COMPUTES
DIFFUSION
COEFFICIENTS

36•LBL 05
 4 ST/ 47 2.08 ST* 45
 GTO 06

42•LBL 02
 RCL 25 .0508 * E↑X
 1.638 * ST* 44 1.75
 ST/ 47 1.6351 FS? 02
 ST* 45 1.3064 FC? 02
 ST* 45 GTO 06

59•LBL 03
 RCL 25 .0471 * E↑X
 1.3067 * ST* 44 2.25
 ST/ 47 2.1868 FS? 02
 ST* 45 2.1064 FC? 02
 ST* 45 GTO 06

76•LBL 04
 BEEP "INVALID TEMP"
 AVIEW PSE
 "FOR HCL FIT" AVIEW

83•LBL 06
 RTN END

01•LBL "HD"
 XEQ "NI" RCL 20 X↑2 4
 * ENTER↑ RCL 26 X↑2
 + SQRT RCL 26 + 2 /
 STO 72 XEQ "SV" RCL 67
 STO 66 RCL 20 STO 72
 XEQ "SY" -12761.02
 RCL 12 / E↑X 2.6 E3
 * ENTER↑ RCL 66
 ENTER↑ RCL 67 /
 ENTER↑ 1 - * 1 +
 ST* 45 CF 22 RTN END

HEAVILY-
DOPED
SUBSTRATE
MODIFICATION
FOR OXIDE
CALCULATION

"INITIALIZE"
KEY

HCL
MODIFICATIONS
FOR DRY
OXIDATION

01•LBL "INIT"
 • INITIALIZE • AVIEW
 EREG 00 CF 22
 2.144 E-9 STO 29
 14269.14 STO 30 .173
 STO 31 23201.86 STO 32
 2 E-6 STO 33 5.94 E-10
 STO 34 8236.66 STO 35
 2.49 STO 36 23201.86
 STO 37 0 STO 38
 1.07 E-9 STO 39
 9048.72 STO 40 4.53
 STO 41 23781.9 STO 42
 0 STO 43 1.68 STO 43
 "QED0" ASTO 69 1 E14
 STO 70 SF 02 CF 06
 CF 07 CF 03 CF 10
 "***PRIDE***" AVIEW
 BEEP RTN END

01LBL 00
 STO Z FC?C 22 GTO 01
 CF 02 RCL Z 100 -
 X=0? SF 02

11LBL 01
 100 STO 66 111 FC? 02
 STO 66 "ORIENT=<"
 FIX 0 ARCL 66 "+>"
 AVIEW RTN END

01LBL "OED0"
 RCL 27 X<0? GTO 00
 X>0? GTO 03 RCL 63
 X<0? GTO 01 3.3
 ST* 21 GTO 03

13LBL 01
 1.8 ST* 21 GTO 03

17LBL 00
 3.3 E-7 FS? 02 7.2 E-7
 STO 66 RCL 14 X=0?
 GTO 03 20882 RCL 12 /
 ENT[↑] RCL 66 * ENTER[↑]
 RCL 14 ENTER[↑] -.2 Y[↑]X
 * 1 + ST* 21

40LBL 03
 CF 22 RTN END

01LBL "OED1"
 RCL 27 X<0? GTO 00
 X>0? GTO 01 RCL 63
 X>0? GTO 02 X=0?
 GTO 02 FC? 02 GTO 02
 -27726.22 RCL 12 /
 ENT[↑] 3.7 E-5 * ST* 21
 GTO 02

22LBL 00
 RCL 63 X<0? GTO 03
 FC? 02 GTO 04
 -33862.65 RCL 12 /
 ENT[↑] 7.5 E-3 * ST* 21
 GTO 02

36LBL 04
 -26450.12 RCL 12 /
 ENT[↑] 1.6 E-5 * ST* 21
 GTO 02

45LBL 03
 FC? 02 GTO 05
 -27146.17 RCL 12 /
 ENT[↑] 4.1 E-5 * ST* 21
 GTO 02

56LBL 05
 -25754.06 RCL 12 /
 ENT[↑] 7.9 E-6 * ST* 21

ENTER/VIEW SILICON ORIENTATION

O.E.D. MODIFICATION BASED ON SUPREM

(DEFAULT VALUES)

O.E.D. MODIFICATION BASED ON C. HILL (PESSEY)

(OPTIONAL VALUES)

65LBL 01
 RCL 63 X>0? GTO 02
 X=0? GTO 02 FC? 02
 GTO 02 -27146.17
 RCL 12 / ENT[↑] 1 9 E-6
 * ST* 21

80LBL 02
 CF 22 RTN END

01LBL "PLOT"
 SF 10 XROM "PRPLOT"
 CF 10 RTN

06LBL "VGNV"
 10[↑]X XEQ "VGS" RTN
 END

01LBL "TQ"
 XEQ "VW" CF 01
 XEQ "NI" RCL 20 STO 72
 1 STO 76 XEQ "DF"
 RCL 15 SQRT RCL 26 *
 1.128 * STO 13 SF 05
 CF 00 CF 04 TONE 9
 XEQ "YQ" RTN

23LBL "QT"
 STO 13 FIX 0 RCL 12
 STO 66 273 ST- 66
 "TEMP=" ARCL 66 "+ C"
 AVIEW PSE XEQ "YQ"
 CF 00 CF 01 XEQ "NI"
 RCL 20 STO 72 1
 STO 76 XEQ "DF" RCL 13
 RCL 26 / X[↑]2 PI * 4
 / RCL 21 / 60 /
 STO 14 FIX 0 TONE 9
 "TIME=" ARCL 14
 "+ MIN" 60 ST* 14
 RCL 14 RCL 21 *
 STO 15 AVIEW CF 22
 RTN END

01LBL "RNG"
 RCL 27 X=0? GTO 01
 X<0? GTO 02 RCL 22
 ENTER[↑] .8638 Y[↑]X
 10.959 E-8 * RCL 18 -
 STO 16 RCL 22 ENTER[↑]
 .8038 Y[↑]X 3.8383 E-8
 * STO 17 GTO 03

24LBL 01
 RCL 22 12.3612 E-8 *
 RCL 18 - STO 16
 RCL 22 ENTER[↑] .8287
 Y[↑]X 7.6046 E-8 *
 STO 17 STO 07

"PLOT"
 KEY
 USED TO
 PLOT VGS
 VS. log(N_{inv})

"T → Q"
 KEY
 (CHEMICAL
 PREDEP)

"Q → t"
 KEY
 (CHEMICAL
 PREDEP)

COMPUTES
 Rp, Sr_p
 USING E_o

(BASED
 ON LSS
 THEORY)

39LBL 02
RCL 22 ENTER↑ .8909
Y₁X 52.2629 E-8 *
RCL 18 - STO 16
RCL 22 ENTER↑ .561
Y₁X 53.4216 E-8 *
STO 17

56LBL 03
CF 22 RTN END

01LBL "RP"
STO 2 FS?C 22 GTO 01
1 E8 ST* 16 GTO 02

08LBL 01
RCL 2 STO 16 SF 03

12LBL 02
FIX 2 "RP=" ARCL 16
"T A" AVIEW 1 E-8
ST* 16 RTN END

01LBL "SDT"
CF 01 STO 73 FIX 0
RCL 12 STO 66 273
ST- 66 "TEMP=" ARCL 66
"T C" AVIEW PSE "XJ="
FIX 3 ARCL 73 "T UM"
AVIEW SF 04 XEQ "NI"
RCL 27 X<0? GTO 01
-4.698 E4 ENTER↑
RCL 12 / E₁X 12 *
STO 21 RCL 73 2 E4 /
ENTER↑ 3 Y₁X RCL 20
* RCL 21 / RCL 13 /
STO 14 RCL 21 * 1/X
ENTER↑ RCL 13 X₁₂ *
RCL 20 * ENTER↑
.3333333 Y₁X .94 *
STO 74 RCL 20 RCL 21
/ RCL 14 / ENTER↑
.1111111 Y₁X 1.7 E18
* ENTER↑ RCL 13
ENTER↑ -.7777773 Y₁X
* STO 75 RCL 20 8 /
RCL 74 / RCL 21 /
RCL 14 / SQRT STO 65
GTO 02

89LBL 01
-40139 RCL 12 / E₁X
.72 * STO 21 RCL 13
RCL 73 / 2.5 E4 *
STO 74 RCL 73 X₁₂
6 E8 / RCL 20 *
RCL 74 / RCL 21 /
STO 14 2.78 E21 RCL 74
/ RCL 73 / STO 75

ENTER/VIEW
Rp (Å)

"X_j → t"
KEY
FOR
SOURCE/DRAIN
DIFFUSIONS
(X_j → SD)

120LBL 02
RCL 14 RCL 21 *
STO 15 60 ST/ 14
FIX 0 TONE 9 "TIME="
ARCL 14 "T MIN" AVIEW
60 ST* 14 PSE PSE
TONE 9 FIX 3 "RS="
ARCL 75 AVIEW PSE PSE
TONE 9 SCI 3 "CS="
ARCL 74 AVIEW CF 22
RTN END

01LBL "SEG"
RCL 27 X<0? GTO 00 10
STO 82 GTO 01

08LBL 00
FC? 02 GTO 02
-11136.89 RCL 12 /
E₁X 2208 * STO 82
GTO 01

19LBL 02
-10556.84 RCL 12 /
E₁X 1126 * STO 82

27LBL 01
RTN END

01LBL "TDF"
ENTER↑ STO 2 "TEMP="
FIX 2 ARCL 2 FC? 10
AVIEW RCL 2 273 +
STO 12 XEQ "NI" RCL 26
2 / RCL 20 / X₁₂ 1
+ SQRT 1/X RCL 26 *
2 / RCL 20 / ABS 1
+ STO 76 RCL 27 X<0?
GTO 01 X=0? GTO 02
"DB=" GTO 03

41LBL 01
"DAS=" GTO 03

44LBL 02
"DP="

46LBL 03
RCL 20 X₁₂ 4 *
ENTER↑ RCL 26 X₁₂ +
SQRT RCL 26 + 2 /
STO 72 XEQ "DF" SCI 3
ARCL 21 TONE 9 FC? 10
AVIEW CF 22 RCL 21
LOG RTN END

01LBL "TN"
XEQ "VH" CF 04 SF 09
CF 08 RCL 15 X=0?
CF 09 XEQ "NI" RCL 29
STO 72 1 STO 76
XEQ "DF" FS? 00 GTO 01
SF 08 E₁X 00 STO 00

COMPUTES
SEGREGATION
COEFFICIENTS

"T → D_i"
KEY
COMPUTES
DIFFUSION
COEFFICIENT.

"t → N_s"
KEY

22LBL 05
FC? 01 GTO 06 RCL 14
3600 / HMS XEQ "TTX"

30LBL 06
RCL 18 RCL 19 - .44
* X¹² -4 / RCL 15 /
E^{TX} RCL 13 * STO 77
PF ENTER[↑] RCL 15 *
SQRT ST/ 77 GTO 08

52LBL 02
RCL 18 STO 19 RCL 15
PI * SQRT 1/X RCL 13
* STO 77 GTO 08

64LBL 01
FS? 03 GTO 03 FC? 09
XEQ "RNG"

69LBL 03
FC? 01 XEQ "CP" FS? 01
XEQ "FP"

74LBL 08
TONE 9 SCI 3 "N(0)="
ARCL 77 AVIEW CF 22
RTN END

01LBL "TOX"
RCL 63 X>0? GTO 01
X<0? GTO 02 RCL 35
CHS RCL 12 / E^{TX}
RCL 34 * STO 44
RCL 37 CHS RCL 12 /
E^{TX} RCL 36 * STO 45
RCL 18 X>0? GTO 03
RCL 38 STO 18 GTO 03

29LBL 01
RCL 40 CHS RCL 12 /
E^{TX} RCL 39 * STO 44
RCL 42 CHS RCL 12 /
E^{TX} RCL 41 * STO 45
RCL 18 X>0? GTO 03
RCL 43 STO 18 GTO 03

52LBL 02
RCL 30 CHS RCL 12 /
E^{TX} RCL 29 * STO 44
RCL 32 CHS RCL 12 /
E^{TX} RCL 31 * STO 45
RCL 18 X>0? GTO 03
RCL 33 STO 18

74LBL 03
1 FS? 06 RCL 64
ST* 44 ST* 45 1
FS? 02 RCL 48 ST/ 45
FS? 08 XEQ "HD" RCL 44
RCL 45 / STO 46

*t → N_s
FOR
CHEMICAL
OR I²
DRIVE-IN
PROFILES*

RCL 44 / STO 47
RCL 63 X>0? GTO 05
X=0? GTO 05 FS? 07
XEQ "HCL" RCL 44
RCL 45 / STO 46

108LBL 05
CF 22 FIX 1 RTN END

01LBL "TSD"
CF 01 XEQ "YW"
XEQ "NI" SF 04 RCL 27
X<0? GTO 01 -4.698 E4
ENTER[↑] RCL 12 / E^{TX}
12 * STO 21 RCL 14 *
ST+ 15 RCL 13 RCL 15
* RCL 20 / ENTER[↑]
.3333333 Y^{TX} 2 E4 *
STO 73 RCL 13 X¹²
RCL 20 * RCL 15 /
ENTER[↑] .3333333 Y^{TX}
.94 * STO 74 RCL 20
RCL 15 / ENTER[↑]
.11111111 Y^{TX} 1.7 E10
* ENTER[↑] RCL 13
ENTER[↑] -.77777778 Y^{TX}
* STO 75 RCL 20 8 /
RCL 74 / RCL 15 /
SQRT STO 65 GTO 02

*"t → x_j"
KEY
FOR
SOURCE/
DRAIN
DIFFUSIONS*

(*t → SD*)

*COMPUTES
OXIDATION
COEFFICIENTS
(B, B/A, T)*

68LBL 01
-40139 RCL 12 / E^{TX}
.72 * STO 21 RCL 14
* ST+ 15 RCL 13 X¹²
RCL 20 * RCL 15 /
ENTER[↑] .3333333 Y^{TX}
1.014 * STO 74 1/X
RCL 13 * 2.5 E4 *
STO 73 RCL 74 * 1/X
2.78 E21 * STO 75

103LBL 02
TONE 9 FIX 3 "XJ="
ARCL 73 "↑ UM" AVIEW
PSE PSE TONE 9 "RS="
ARCL 75 AVIEW PSE PSE
SCI 3 TONE 9 "CS="
ARCL 74 AVIEW CF 22
RTN END

01LBL "TTX"
HR ENTER[↑] 60 *
STO 14 FIX 0 "TIME="
ARCL 14 "↑ MIN" FC? 10
AVIEW 60 ST* 14
XEQ "TOX" RCL 14
RCL 47 + 4 * RCL 44
* ENTER[↑] RCL 46 X¹²
/ 1 + SQRT 1 -
RCL 46 * 2 E-8 /
STO 18 CF 06 CF 07
TONE 9 "TOX=" ARCL 18
"↑ A" FC? 10 AVIEW

*"t → Tox"
KEY*

51LBL "TXT"
 STO 19 FIX 1 "TOX="
 ARCL 19 "+ A" AVIEW
 1 E-8 ST* 19 XEQ "TOX"
 RCL 19 2 * RCL 46 /
 1 + X¹² 1 - ENTER↑
 RCL 46 X¹² * 4 /
 RCL 44 / RCL 47 -
 3600 / HMS STO 14
 FIX 4 "TIME=" ARCL 14
 CF 06 CF 07 TONE 9
 RCL 14 HR 3600 *
 STO 14 RCL 19 STO 18
 AVIEW RTN END

01LBL "TX"
 STO 2 FS?C 22 GTO 01
 1 E8 ST* 18 GTO 02

08LBL 01
 RCL 2 STO 18

11LBL 02
 "TOX=" FIX 2 ARCL 18
 "+A" 1 E-8 ST* 18
 AVIEW RTN END

01LBL "WBX"
 STO 2 FS?C 22 GTO 01
 1 E4 ST* 61 GTO 02

08LBL 01
 RCL 2 STO 61

11LBL 02
 "WBX=" FIX 3 ARCL 61
 "+UM" 1 E-4 ST* 61
 AVIEW RTN END

01LBL "dRP"
 STO 2 FS?C 22 GTO 01
 1 E8 ST* 17 GTO 02

08LBL 01
 RCL 2 STO 17 SF 03

12LBL 02
 FIX 2 "dRP=" ARCL 17
 "+A" AVIEW 1 E-8
 ST* 17 RTN END

01LBL "PSI"
 RCL 93 XEQ "CX" 1/X
 RCL 26 * LH RCL 58 +
 1 + STO 54 RCL 93
 RCL 97 / X¹² 2 /
 ST* 54 48 ST/ 54 RTN

"TOX → t"
 KEY

ENTER/VIEW
 TOX (Å)

ENTER/VIEW

W_bx (μm)

ENTER/VIEW
 ΔR_p(Å)

COMPUTES
 PSIⁱ⁺¹

23LBL "PSIU"
 3.7043 E-5 RCL 53 *
 RCL 70 * RCL 18 *
 RCL 57 / STO 89
 1.8522 E-5 RCL 70 *
 RCL 18 * RCL 57 /
 X¹² RCL 89 + LN
 STO 89 RCL 26 1.45 E10
 / LN 2 * ST* 89
 RCL 58 48 * ST* 89
 40 ST/ 89 RTN

68LBL "DELI"
 RCL 93 RCL 97 /
 RCL 49 + ENTER↑ 2
 SQRT / STO 52 RTN

72LBL "DELU"
 RCL 55 40 * 1 -
 SQRT STO 53 RTN

81LBL "AB"
 RCL 18 RCL 97 /
 4.2426 * STO 57 RTN

89LBL "LB"
 1.6197 E5 RCL 26 /
 SQRT STO 97 RTN

96LBL "DELYT"
 RCL 54 RCL 55 - 40 *
 STO 90 RCL 52 RCL 53
 - RCL 57 * RCL 90 +
 40 / STO 90 RTN

114LBL "M0"
 RCL 93 RCL 16 -
 RCL 17 / ENTER↑ 2
 SQRT / X¹² CHS E^{1X}
 STO 49 RCL 16 RCL 17
 / ENTER↑ 2 SQRT /
 XEQ "EF" ST+ 49 RCL 13
 RCL 26 / RCL 97 / 2
 / ST* 49 RTN

144LBL "M1"
 RCL 93 RCL 16 -
 RCL 17 / ENTER↑ 2
 SQRT / X¹² CHS E^{1X}
 STO 50 RCL 16 RCL 17
 / ENTER↑ 2 SQRT /
 X¹² CHS E^{1X} ST- 50
 RCL 13 RCL 17 *
 RCL 26 / ENTER↑
 RCL 97 X¹² / -.3989
 * ST* 50 RCL 16
 RCL 97 / RCL 49 *
 ST+ 50 RTN

188LBL "CX"
 ENTER↑ RCL 16 -
 RCL 17 / X¹² -2 /

COMPUTES
 PS₄ⁱ⁺¹

COMPUTES
 Δi(w)

COMPUTES
 Δu

COMPUTES
 a

COMPUTES
 L_B

COMPUTES
 ΔV_{th}

COMPUTES
 M₀(w)

COMPUTES
 M₁(w)

COMPUTES
 N_A(x)

203LBL "IMP"
CF 03 XEQ "RNG"
XEQ "IX" XEQ "IXY" PSE
XEQ "RP" PSE XEQ "dRP"
TONE 9 RTN

214LBL "M8"
RCL 16 RCL 17 /
ENTER↑ 2 SQRT /
XEQ "EF" 1 + RCL 13
* 2 / RCL 26 /
RCL 97 / STO 49 RTN

235LBL "M1"
RCL 16 RCL 17 / X↑2
-2 / E↑X STO 50
RCL 16 RCL 17 /
ENTER↑ 2 SQRT /
XEQ "EF" 1 + 1/X
RCL 17 * RCL 97 /
ENTER↑ 2 ENTER↑ PI /
SQRT * ST* 50 RCL 16
RCL 97 / ST+ 50
RCL 49 ST* 50 RTN END

01LBL "BCL"
XEQ "SEG" RCL 46 X↑2
4 / RCL 44 / RCL 14
+ 1/X RCL 44 * SQRT
STO 68 RCL 82 -.44 *
1 + 2 / RCL 82 /
ST* 68 RTN

27LBL "ACL"
RCL 18 RCL 19 - .44
* 2 / ENTER↑ RCL 21
ENTER↑ RCL 14 * SQRT
/ XEQ "EF" CHS 1 +
RCL 68 * STO 85
RCL 18 RCL 19 - .44
* X↑2 -4 / RCL 21 /
RCL 14 / E↑X ENTER↑
RCL 21 ENTER↑ PI /
ENTER↑ RCL 14 / SQRT
* ST+ 85 RCL 18
RCL 19 - .44 *
STO 78 XEQ "SG" RCL 81
STO 84 -1 ST* 78
XEQ "SG" RCL 81 ST+ 84
RCL 28 ST* 84 RCL 18
RCL 19 - .44 * 2 /
RCL 14 / ENTER↑
RCL 24 ENTER↑ 1 + /
RCL 68 + ST* 84
RCL 18 RCL 19 - .44
* STO 78 XEQ "SG"
RCL 81 STO 83 -1
ST* 78 XEQ "SG" RCL 81
ST- 83 RCL 24 RCL 16
* RCL 21 * RCL 23 *

COMPUTES Imax, Rp, SRp FOR IMPLANT

RCL 17 / ST* 83
RCL 21 RCL 14 * 8 *
SQRT ST/ 83 RCL 24 1
+ ENTER↑ 1.5 Y↑X
ST/ 83 RCL 83 RCL 84
- RCL 85 / STO 65
RTN END

COMPUTES

m_o

COMPUTES

m_i

COMPUTES

β

(FOR OXID.
AMB. DRIVE-IN)

COMPUTES

A

(FOR OXID.
AMB. DRIVE-IN)

01LBL "BOX"
"BOX PROFILE" AVIEW
RCL 23 RCL 26 / LN 2
* ENTER↑ RCL 17 X↑2
* SQRT RCL 16 +
STO 61 RCL 16 RCL 17
/ ENTER↑ 2 SQRT /
XEQ "EF" STO 62 RCL 61
RCL 16 - RCL 17 /
ENTER↑ 2 SQRT /
XEQ "EF" ENTER↑ RCL 62
+ RCL 23 * RCL 17 *
RCL 61 / ENTER↑ PI
ENTER↑ 2 / SQRT *
RCL 26 + STO 62 SCI 3
"NBX=" ARCL 62 TONE 9
AVIEW PSE PSE FIX 3
1 E4 ST* 61 "WBX="
ARCL 61 "+ UM" 1 E4
ST/ 61 TONE 9 AVIEW
CF 22 RTN

75LBL "dVT"
FS?C 22 STO 58 FIX 3
"VSB=" ARCL 58 "+ V"
FC? 10 AVIEW XEQ "IXY"
XEQ "YT" FIX 3 "dVT="
ARCL 98 "+ V" TONE 9
FC? 10 AVIEW RTN END

COMPUTES N_{bx}, W_{bz} FOR A GAUSSIAN PROFILE

"V_b → V_H"
FUNCTION

ENTER/VIEW
TEMPERATURE
(°C)

01LBL "T"
STO 2 FS?C 22 GTO 01
273 ST- 12 GTO 02

08LBL 01
RCL 2 STO 12

11LBL 02
"TEMP=" FIX 1 ARCL 12
"+ C" AVIEW 273
ST+ 12 RTN

20LBL "BR"
-1 STO 27 CF 22
"BORON" AVIEW RTN END

"BORON"
KEY

01LBL "CP"
XEQ "IX" XEQ "R"
XEQ "GM" 0 STO 78
XEQ "PF" RCL 18 STO 19

COMPUTE
N(0)
(INERT)

```

11LBL "PF"
-1 ST* 78 XEQ "SG"
RCL 81 STO 77 -1
ST* 78 XEQ "SG" RCL 81
ST* 77 RCL 28 ST* 77
RTN

```

```

25LBL "FP"
RCL 18 STO 19 RCL 14
3600 / HMS XEQ "TTX"
XEQ "BCL" XEQ "GM"
XEQ "IX" XEQ "R"
XEQ "ACL" RCL 18
RCL 19 - .44 *
STO 78 XEQ "FF" RTN

```

```

46LBL "FF"
XEQ "PF" RCL 21 RCL 14
* SQRT 2 * 1/X
ENTER↑ RCL 78 *
XEQ "EF" CHS 1 +
RCL 65 * ST* 77 RTN
END

```

```

81LBL "EF"
STO 79 X↑2 ENTER↑ -4
* PI / EAX CHS 1 +
SQRT STO 80 RCL 79
X>0? GTO 81 -1 ST* 80
28LBL 81
RCL 80 RTN END

```

```

81LBL "FW"
XEQ "M0" XEQ "M1"
XEQ "DELI" RCL 93
RCL 97 / X↑2 2 / 1
+ STO 92 RCL 58
ST* 92 RCL 93 XEQ "CX"
1/X RCL 26 * LH
ENTER↑ RCL 58 ENTER↑
40 * - ST* 92 RCL 26
1.45 E10 / LN 2 *
ST- 92 1.8522 E-5
RCL 78 * RCL 18 *
RCL 57 / X↑2 STO 55
3.7043 E-5 RCL 78 *
RCL 52 * RCL 18 *
RCL 57 / RCL 55 + LH
ST- 92 RCL 92 RTN

```

```

68LBL "YT"
XEQ "LB" XEQ "AB"
RCL 26 1.45 E10 / LN
20 / RCL 58 +
1.2958 E7 * RCL 26 /
SQRT STO 53 STO 93
XEQ "IXQ" RCL 23
1.45 E10 / LN 20 /
RCL 58 + 1.2958 E7 *
RCL 23 / SQRT STO 90
XEQ "ROOT" XEQ "PSII"

```

COMPUTE N(x) (INERT AMB)

COMPUTE N(0) (OXD. AMB)

COMPUTE N(x) (OXD AMB)

ERROR FUNCTION (erfc x)

COMPUTE f(w) FOR A GAUSSIAN

COMPUTE δV_{th} FOR A GAUSSIAN PROFILE

```

100LBL 80
XEQ "DELU" XEQ "PSIU"
RCL 89 RCL 55 - ABS
STO Y 1 E-4 X>Y?
GTO 81 RCL 89 STO 55
GTO 80

```

```

114LBL 81
XEQ "DELYT" RTN END

```

```

81LBL "WH"
HR ENTER↑ 60 *
STO 14 FIX 0 RCL 12
STO 66 273 ST- 66
"TEMP=" ARCL 66 ↑ C
AVIEW PSE "TIME="
ARCL 14 ↑ MIN AVIEW
60 ST* 14 RTN

```

```

24LBL "IEF"
CHS 1 + X↑2 CHS 1
+ LN PI * -4 /
SQRT RTN

```

```

39LBL "SG"
RCL 24 1 + 2 * SQRT
RCL 17 * 1/X ENTER↑
RCL 24 ENTER↑ RCL 78
* ENTER↑ RCL 16 + *
XEQ "EF" 1 + STO 81
RCL 78 RCL 16 - X↑2
-4 / RCL 15 / ENTER↑
1 ENTER↑ RCL 24 + /
E↑X ST* 81 RTN

```

```

79LBL "IX"
FS? 83 XEQ "IXQ"
RCL 16 RCL 17 /
ENTER↑ 2 SQRT /
XEQ "EF" 1 + 1/X
RCL 13 * RCL 17 /
ENTER↑ 2 ENTER↑ PI /
SQRT * STO 23 RTN

```

```

106LBL "GM"
RCL 17 X↑2 4 *
ENTER↑ RCL 15 ENTER↑
8 * + SQRT 1/X
RCL 23 * RCL 17 *
STO 28 RTN

```

```

125LBL "R"
RCL 17 X↑2 2 /
RCL 15 / STO 24 RTN
END

```

```

81LBL "UU"
FS?C 22 STO 98 "U="
FIX 2 ARCL 98 AVIEW

```

ENTER TIME
(HH.MMSS)
AND VIEW
TEMP (°C)
AND TIME
(MIN)

COMPUTE
erfc⁻¹(u)

COMPUTE
 \sqrt{x}

COMPUTE
Imax

COMPUTE
 γ

COMPUTE
 γ

ENTER/VIEW
MOBILITY

09LBL "MYY"
FS?C 22 STO 70 SCI 2
"NINV=" ARCL 70 AVIEW
RTN

17LBL "YDS"
FS?C 22 STO 99 "YDS="
FIX 2 ARCL 99 AVIEW
RTN

25LBL "VGS"
FS?C 22 STO 51 "VGS="
FIX 2 ARCL 51 AVIEW
RTN

33LBL "WL"
FS?C 22 STO 96 "W/L="
FIX 3 ARCL 96 AVIEW
RTN

41LBL "IDS"
STO 99 CF 22 FIX 2
"YDS=" ARCL 99 "+ Y"
FC? 10 AVIEW PSE
RCL 51 RCL 59 X=Y?
GTO 02 0 STO 95
GTO 01

58LBL 02
RCL 51 RCL 59 -
RCL 99 X>Y? GTO 00
X<Y ENTER↑ RCL 99
ENTER↑ 2 / - RCL 99
* RCL 98 * RCL 96 *
RCL 18 / 3.454 E-13 *
STO 95 GTO 01

84LBL 00
X<Y X×2 RCL 98 *
RCL 96 * RCL 18 /
1.7277 E-13 * STO 95

96LBL 01
"IDS=" ENG 3 ARCL 95
TONE 9 FIX 3 FC? 10
AVIEW RCL 95 RTN END

01LBL "MVG"
STO 70 SCI 2 "NINV="
ARCL 70 FC? 10 AVIEW
XEQ "LB" XEQ "AB"
FC? 00 GTO 01 RCL 26
1.45 E10 / LN 20 /
RCL 58 + 1.2958 E7 *
RCL 26 / SQRT STO 53
STO 93 XEQ "IXQ"
RCL 23 1.45 E10 / LN
80 / RCL 58 +
1.2958 E7 * RCL 23 /
SQRT STO 90

ENTER/VIEW
Ninv (cm-3)

ENTER/VIEW
Vds (v)

ENTER/VIEW
Vgs (v)

ENTER/VIEW
W/L

"Vds → Ids"
key

XEQ "ROOT*" XEQ "PSII"
RCL 70 RCL 18 *
4.6304 E-7 * RCL 54 +
RCL 58 - STO 51
RCL 52 RCL 57 * 40 /
ST+ 51 GTO 00

61LBL 01
.4 RCL 58 + STO 55

66LBL 02
XEQ "DELU" XEQ "PSIU"
RCL 89 RCL 55 - ABS
1 E-4 X>Y? GTO 03
RCL 89 STO 55 GTO 02

79LBL 03
RCL 70 RCL 18 *
4.6304 E-7 * RCL 55 +
RCL 58 - STO 51
RCL 53 RCL 57 * 40 /
ST+ 51

96LBL 00
FIX 3 "VGS=" ARCL 51
"+ "+ Y" CF 22
TONE 9 FC? 10 AVIEW
RCL 51 RTN

108LBL "IXQ"
RCL 23 ENTER↑ PI
ENTER↑ 2 / SQRT *
RCL 17 * STO 13
RCL 16 RCL 17 /
ENTER↑ 2 SQRT /
XEQ "EF" 1 + ST* 13
RTN

132LBL "IXY"
FS? 22 STO 23 FS?C 22
SF 03 "IMAX=" SCI 3
ARCL 23 AVIEW RTN END

COMPUTE
Q
GIVEN
Imax

ENTER/VIEW
Imax

01LBL "NX"
STO 77 "N(X)=" SCI 3
ARCL 77 AVIEW FS? 00
GTO 01 FC? 05 GTO 02
RCL 77 RCL 26 /
XEQ "IEF" ENTER↑
RCL 15 ENTER↑ 4 *
SQRT * 1 E4 * STO 86
GTO 00

"N(X) → X"
key

26LBL 02
RCL 15 PI * SQRT
RCL 77 * 1/X RCL 13
* LN RCL 15 * 4 *
SQRT STO 86 RCL 18
RCL 19 - .44 *
ST- 86 1 E4 ST* 86
RTN 00

52LBL 01
 RCL 15 X>0? GTO 03
 FC? 03 XEQ "RNG"
 XEQ "IX" RCL 23 RCL 77
 / LN 2 * ENTER↑
 RCL 17 X↑2 * SQRT
 RCL 16 + 1 E4 *
 STO 86 GTO 00

76LBL 03
 FC? 04 GTO 04 RCL 27
 X>0? GTO 05 RCL 77
 RCL 74 / CHS 1 +
 ENTER↑ 1.5 Y↑X RCL 73
 * STO 86 FC? 01
 GTO 00 RCL 18 RCL 19
 - .44 E4 * ST- 86
 GTO 00

103LBL 05
 RCL 77 RCL 74 / 1 -
 -1.8 * .7569 + SQRT
 .87 - .9 / RCL 65 /
 1 E4 * STO 86 FC? 01
 GTO 00 RCL 18 RCL 19
 - .44 E4 * ST- 86
 GTO 00

132LBL 04
 RCL 28 2 * RCL 77 /
 LN RCL 15 * 4 *
 ENTER↑ RCL 24 ENTER↑
 1 + * SQRT RCL 16 +
 1 E4 * STO 86 FC? 01
 GTO 00 RCL 18 RCL 19
 - .44 E4 * ST- 86

163LBL 00
 FIX 3 "X=" ARCL 86
 "T UM" TONE 9 AVIEW
 CF 22 RTN END

01LBL "OXIDE"
 STO 79 XEQ "ET" RCL 79
 60 / HMS XEQ "TTX"
 RTN END

01LBL "ROOT"
 RCL 90 STO 93 STO 56
 XEQ "FW" STO 94 RCL 53
 STO 93 XEQ "FW" STO 95
 RCL 94 * X>0? GTO 00

15LBL 01
 RCL 53 RCL 53 RCL 90
 - RCL 95 RCL 94 - /
 RCL 95 * - STO 93
 ENTER↑ RCL 56 - ABS
 5 E-7 X>Y? GTO 02
 RCL 93 XEQ "FW" STO 96
 X=0? GTO 02 ABS 1 E-2
 X>Y? GTO 02 RCL 93
 STO 56 RCL 96 RCL 95
 * XEQ "STO 07 RCL 57

55LBL 04
 RCL 93 STO 53 RCL 96
 STO 95 GTO 01

61LBL 00
 "ROOT ERROR" AVIEW
 BEEP STOP

66LBL 03
 2 ST/ 94 GTO 04

70LBL 02
 RTN END

01LBL "SYT"
 STO 2 "TEMP=" FIX 1
 ARCL 2 "T C" FC? 10
 AVIEW RCL 2 273 +
 STO 12 XEQ "NI" RCL 20
 X↑2 4 * ENTER↑
 RCL 26 X↑2 + SQRT
 RCL 26 + 2 / STO 72
 XEQ "SY" SCI 3 "SIY="
 ARCL 67 TONE 9 FC? 10
 AVIEW CF 22 RCL 67
 LOG RTN END

01LBL "TH"
 SF 10 STO 73 FIX 0
 RCL 12 STO 66 273
 ST- 66 "TEMP=" ARCL 66
 "T C" AVIEW PSE FIX 3
 "XJ=" ARCL 73 "T UM"
 AVIEW CF 04 CF 09
 CF 08 1 E-4 ST* 73
 XEQ "NI" RCL 20 STO 72
 1 STO 76 FS? 00
 GTO 01 CF 05

32LBL 00
 3600 STO 14

35LBL 04
 FS? 01 GTO 02 RCL 18
 STO 19 GTO 05

41LBL 02
 RCL 18 STO 19 RCL 14
 3600 / HMS XEQ "TTX"

49LBL 05
 RCL 18 RCL 19 - .44
 * RCL 73 + X↑2 4 /
 STO 87 XEQ "DF" RCL 21
 RCL 14 * PI * SQRT
 RCL 26 * 1/X RCL 13
 * LN RCL 21 * ST/ 87
 RCL 87 RCL 14 - ABS
 30 X>Y? GTO 03 RCL 87
 STO 14 RCL 19 STO 18
 GTO 04

"T → SiV(T)"
 KEY

"Xj → t"
 KEY

FOR:
 CHEMICAL
 OR I²
 DRIVE-IN
 PROFILES

OXIDE
 PLOT
 FUNCTION

COMPUTES
 W'
 FOR
 f(W') = 0

GTO 04

89LBL 03
 CF 10 RCL 19 STO 18
 FS? 01 GTO 11 RCL 18
 STO 19 GTO 12

98LBL 11
 RCL 18 STO 19 RCL 14
 3600 / HMS XEQ "TTX"

106LBL 12
 RCL 87 STO 14 RCL 21
 * STO 15 RCL 18
 RCL 19 - .44 * X¹²
 -4 / RCL 15 / E^{1X}
 RCL 13 * STO 77 PI
 ENTER[↑] RCL 15 * SQRT
 ST/ 77 GTO 06

133LBL 01
 FC? 03 XEQ "RNG"
 XEQ "IX" 3600 STO 14

139LBL 07
 FS? 01 GTO 08 RCL 18
 STO 19 GTO 09

145LBL 08
 RCL 18 STO 19 RCL 14
 3600 / HMS XEQ "TTX"

153LBL 09
 XEQ "DF" XEQ "R"
 XEQ "GM" RCL 18 RCL 19
 - .44 * RCL 73 +
 RCL 16 - X¹² 4 /
 RCL 21 / STO 87 2
 ENTER[↑] RCL 28 *
 RCL 26 / LN ST/ 87
 RCL 17 X¹² 2 /
 RCL 21 / ST- 87
 RCL 87 RCL 14 - ABS
 60 X>Y? GTO 10 RCL 87
 STO 14 RCL 19 STO 18
 0 STO 15 GTO 07

201LBL 10
 CF 10 RCL 19 STO 18
 RCL 14 RCL 21 *
 STO 15 RCL 87 STO 14
 FC? 01 XEQ "CP" FS? 01
 XEQ "FP"

215LBL 06
 RCL 87 3600 / HMS
 STO 87 FIX 4 TONE 9
 "TIME=" ARCL 87 AVIEW
 PSE PSE SCI 3 "N<0>"
 ARCL 77 TONE 9 AVIEW
 CF 22 CF 06 CF 07 RTN
 END

01LBL "TTX"
 HR ENTER[↑] 60 *
 STO 14 FIX 0 "TIME="
 ARCL 14 "T MIN" FC? 10
 AVIEW 60 ST* 14
 XEQ "TOX" RCL 14
 RCL 47 + 4 * RCL 44
 * ENTER[↑] RCL 46 X¹²
 / 1 + SQRT 1 -
 RCL 46 * 2 E-8 /
 STO 18 "TOX=" ARCL 18
 "T A" FC? 10 AVIEW
 1 E-8 ST* 18 RCL 18
 1 E8 * RTN END

" $t \rightarrow \text{Tox}$ "
 FUNCTION
 * FLAGS
 6 AND 7
 ARE NOT
 CLEARED
 (USED WITH
 TN*)

01LBL "VTH"
 STO 58 FIX 3 "VSB="
 ARCL 58 "T V" FC? 10
 AVIEW CF 22 FS? 00
 GTO 01 RCL 26 1.45 E10
 / LN .0518 * STO 54
 RCL 58 + RCL 26 *
 SQRT RCL 18 *
 1.667 E-3 * RCL 54 +
 RCL 60 + STO 59
 GTO 00

" $V_b \rightarrow V_h$ "
 KEY

34LBL 01
 RCL 62 1.45 E10 / LN
 .0518 * STO 54 RCL 61
 X¹² RCL 62 *
 7.718 E-8 * RCL 54 -
 STO 56 RCL 58 X>Y?
 GTO 02 RCL 54 RCL 58
 + RCL 62 * SQRT
 RCL 18 * 1.667 E-3 *
 RCL 54 + RCL 60 +
 STO 59 GTO 00

70LBL 02
 RCL 62 RCL 26 -
 ENTER[↑] RCL 61 X¹² *
 -7.718 E-8 * RCL 54 +
 RCL 58 + RCL 26 *
 SQRT RCL 18 *
 1.667 E-3 * RCL 60 +
 RCL 54 + STO 59
 RCL 62 RCL 26 -
 RCL 61 * RCL 18 *
 4.63 E-7 * ST+ 59

106LBL 00
 "VTH=" ARCL 59 "T V"
 TONE 9 FC? 10 AVIEW
 RCL 59 RTN END

01LBL "XN"
 STO 86 "X=" FIX 3
 ARCL 86 "T UM" FC? 10
 AVIEW 1 E-4 ST* 86
 FS? 00 GTO 01 FC? 05
 GTO 02 RCL 15 4 *
 SQRT 1/X RCL 86 *
 XEQ "EF" CHS 1 +

" $x \rightarrow N(x)$ "
 KEY

OPTIONAL PROGRAMS:

30•LBL 02
 RCL 18 RCL 19 - .44
 * RCL 86 + X¹² -4 /
 RCL 15 / E^{1X} RCL 13
 * ENTER↑ PI ENTER↑
 RCL 15 * SQRT /
 STO 77 GTO 00

55•LBL 01
 RCL 15 X>0? GTO 03
 FC? 03 XEQ "RNG"
 XEQ "IX" RCL 86 RCL 16
 - RCL 17 / X¹² -2 /
 E^{1X} RCL 23 * STO 77
 GTO 00

75•LBL 03
 FC? 04 GTO 04 FC? 01
 GTO 05 RCL 18 RCL 19
 - .44 * ST+ 86

86•LBL 05
 RCL 27 X>0? GTO 06
 RCL 86 RCL 73 / 1 E4
 * ENTER↑ .667 Y^{1X}
 CHS 1 + RCL 74 *
 STO 77 GTO 00

105•LBL 06
 RCL 65 RCL 86 * -.87
 * 1 + STO 77 RCL 65
 RCL 86 * X¹² .45 *
 ST- 77 RCL 74 ST* 77
 GTO 00

124•LBL 04
 RCL 86 STO 78 FC? 01
 XEQ "PF" FC? 01 GTO 00
 RCL 18 RCL 19 - .44
 * RCL 86 + STO 78
 XEQ "FF"

10•LBL 00
 1 3 TONE 9 "N(X)="
 1 77 FC? 10 AVIEW
 2 RCL 77 X<=0? 1
 RTN END

01•LBL "CV"
 AREAC(M+2)? PROMPT
 STO 04 "CMAX(PF)?"
 PROMPT STO 00
 "CMIN(PF)?* PROMPT
 STO 01 "CV MEASURE"
 AVIEW 1 E16 STO 26
 .34554 RCL 04 *
 RCL 00 / STO 18

21•LBL 00
 RCL 00 RCL 01 / 1 -
 RCL 18 * 3 * X¹²
 1/X 6.712 E5 * STO 02
 RCL 26 1.45 E10 / LH
 ST* 02 RCL 02 RCL 26
 - ABS 1 E13 X>Y?
 GTO 01 RCL 02 STO 26
 GTO 00

51•LBL 01
 1.678 E5 RCL 26 /
 SQRT RCL 18 / 3 / 1
 + 1/X RCL 00 *
 STO 03 1 E8 ST* 18
 FIX 2 "TOX=" ARCL 18
 "T A" TONE 9 AVIEW
 PSE PSE 1 E-8 ST* 18
 SCI 2 "NB=" ARCL 26
 TONE 9 AVIEW PSE PSE
 FIX 2 "CFB=" ARCL 03
 "T PF" TONE 9 AVIEW
 CF 22 RTN END

01•LBL "VTH"
 EREG 00 CLE FIX 3
 FS? 00 GTO 05 71
 STO 53 "POINTS?"
 PROMPT STO 11

12•LBL 00
 "VTH,VSS" TONE 4
 PROMPT STO IND 53
 RCL Y ENTER↑ 1 ST+ 53
 RCL Y STO IND 53 1
 ST+ 53 DSE 11 GTO 00
 .7 STO 54 XEQ "HAT"

30•LBL 01
 RCL 53 71 - 2 /
 STO 11 71 STO 53

39•LBL 02
 RCL 54 RCL IND 53 +
 SQRT STO Y 1 ST+ 53
 RCL IND 53 STO Y RDN
 X>Y Σ+ 1 ST+ 53
 DSE 11 GTO 02 RCL 00
 X¹² RCL 05 / CHS

"CV-DATA"
 KEY

"Vt-DATA"
 KEY

RCL 08 RCL 02 *
 RCL 05 / CHS RCL 04
 + ST* 09 RCL 00
 RCL 09 * CHS RCL 02
 + RCL 05 / STO 10
 RCL 09 RCL 18 / X12
 3.594 E5 * STO 26
 1.45 E10 / LH .0518
 * STO 55 RCL 54 -
 ABS 1 E-3 X>Y? GTO 03
 RCL 55 STO 54 GTO 01

105LBL 03
 RCL 00 RCL 02 *
 RCL 05 / CHS RCL 04
 + X12 STO 06 RCL 00
 X12 RCL 05 / CHS
 RCL 01 + ST/ 06
 RCL 02 X12 RCL 05 /
 CHS RCL 03 + ST/ 06
 RCL 10 RCL 55 -
 STO 60 SCI 2 "HB="
 ARCL 26 TONE 9 AVIEW
 PSE PSE FIX 4 "VFB="
 ARCL 60 GTO 04

147LBL 05
 71 STO 53 .7 STO 54
 3 STO 11

154LBL 06
 "VTH, VSB?" TONE 4
 PROMPT X>Y STO IND 53
 1 ST+ 53 RCL Z RCL 54
 + SQRT STO IND 53 1
 ST+ 53 DSE 11 GTO 06
 RCL 71 RCL 72 Σ+
 RCL 73 RCL 74 Σ+
 RCL 75 RCL 76 Σ+
 RCL 00 X12 -3 /
 RCL 01 + 1/X STO 06
 RCL 00 RCL 02 * -3 /
 RCL 04 + ST* 06

196LBL 07
 "VTH, VSB?" TONE 4
 PROMPT X>Y STO IND 53
 1 ST+ 53 RCL Z RCL 54
 + SQRT STO IND 53
 RCL 53 1 - STO 11
 RCL IND 11 STO 07 2
 ST- 11 RCL IND 11
 ST- 07 1 ST+ 11
 RCL IND 11 STO 56
 RCL IND 53 RCL 56 -
 ST/ 07 1 ST+ 53
 RCL 07 RCL 06 - LASTX
 / ABS .3 X>Y? GTO 07
 "VTH, VSB?" TONE 4
 PROMPT X>Y STO IND 53
 1 ST+ 53 RCL Z RCL 54
 + SQRT STO IND 53
 XEQ "ENH" 1 ST+ 53
 RCL 53 75 - 2 /
 STO 11 71 STO 53 CLE

"VL-DATA"
KEY

RCL IND 53 STO Y 1
 ST+ 53 RCL IND 53
 STO Y PPN S+ 1
 ST+ 53 DSE 11 GTO 06
 RCL 06 X12 RCL 05 /
 CHS RCL 01 + 1/X
 STO 09 RCL 00 RCL 02
 * RCL 05 / CHS
 RCL 04 + ST* 09
 RCL 00 RCL 09 * CHS
 RCL 02 + RCL 05 /
 STO 10 RCL 09 RCL 18
 / X12 3.594 E5 *
 STO 62 RCL 18 RCL 54
 - STO 60 RCL 00
 RCL 02 * RCL 05 /
 CHS RCL 04 + X12
 STO 06 RCL 00 X12
 RCL 05 / CHS RCL 01
 + ST/ 06 RCL 02 X12
 RCL 05 / CHS RCL 03
 + ST/ 06 1 ST+ 53
 RCL 62 1/X 1.296 E7 *
 SQRT RCL IND 53 *
 1 E4 * STO 61 2
 ST+ 53 RCL 62 1.45 E10
 / LH .0518 * STO 54
 RCL IND 53 X12 .7 -
 STO IND 53

365LBL 09
 RCL 61 X12 -7.718 E-16
 * ENTER↑ RCL 62
 ENTER↑ RCL 26 - *
 RCL 54 + RCL IND 53 +
 RCL 26 * SQRT RCL 18
 * -1.667 E-3 * RCL 54
 - RCL 60 - STO 10 1
 ST- 53 RCL IND 53
 ST+ 18 1 ST+ 53
 RCL 62 RCL 26 - 1/X
 RCL 18 / 2.16 E10 *
 ST* 10 RCL 18 RCL 61
 - ABS .005 X>Y?
 GTO 10 RCL 10 STO 61
 GTO 09

417LBL 10
 RCL 61 X12 RCL 62 *
 7.718 E-16 * RCL 54 -
 STO 56 SCI 2 "HBX="
 ARCL 62 TONE 9 AVIEW
 PSE PSE FIX 3 "WGX="
 ARCL 61 "UM" 1 E-4
 ST* 61 TONE 9 AVIEW
 PSE PSE "VFB="
 ARCL 60 "V" TONE 9
 AVIEW PSE PSE "VC="
 ARCL 56

453LBL 04
 "V" TONE 9 AVIEW
 PSE PSE FIX 4 "R2="
 ARCL 06 TONE 9 CF 22
 AVIEW RTN .END.



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February 28, 1985

Cheryle Price
2833 N. Bristols
Santa Ana, CA 92706

Subject: PRIDE A Portable Process and Device Design System
for the HP41CV Hand-Held Calculator

Dear Cheryle,

We indeed appreciate hearing from you and knowing of your interest in the Hewlett-Packard PRIDE program for the hand-held 41CV calculator. This program is not yet available for sale by Hewlett-Packard Company however, we are making a few prototype ROMs available to select universities and companies for evaluation. Since these are prototype in nature, there is no guarantee that the programs will be error free or supported by Hewlett-Packard Company.

We are forwarding to you at this time a PRIDE ROM, the PRIDE ROM overlay, and a complete set of existing documentation at no cost with a request that we receive in return from you your critical evaluation of the program and its value to you in your research and development efforts. We feel this may very well be an important capability for many future CAD efforts and are therefore soliciting your assistance.

Thank you again very much for your interest in Hewlett-Packard Company and our products.

Sincerely,

A handwritten signature in black ink, appearing to read "Nabi Bayazit".

Nabi Bayazit
Engineering Productivity Division
Hewlett-Packard Company

/srm

