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ภาคผนวก

ภาคผนวก ก.

โปรแกรมการวิเคราะห์ผลของสิ่งประดิษฐ์มอส

เขียนโดย นาย ธนวิชญ์ ชุลิกาวิทย์

1 มกราคม 2531

```
10                      !!!!!!!!!!!!!!!!!!!!!!!
20                      !! MAIN MENU PROGRAM !!
30                      !!       "MENU"      !!
40                      !!!!!!!!!!!!!!!!!!!!!!!
50        PRINT CHR$(12)
60        PRINT CHR$(132)
70        PRINT TABXY(15,2);"MOS's characteristics program on HEWLETT PACKARD sy
stem."
80        PRINT CHR$(128)
90        PRINT TABXY(15,4);"                                   BY Mr. Dhanavich chuli
kavit"
100       PRINT TABXY(15,6);"These programs are used for measuring the character
istics -"
110       PRINT TABXY(10,7);"of devices which are fabricated by MOS technology.O
n these pro -"
120       PRINT TABXY(10,8);"gram,soaetime,the alpha and graphics are shown on t
he screen in-"
130       PRINT TABXY(10,9);"the same time.If you'd like to see clearly each one
,please press"
140       PRINT TABXY(10,10);"the ALPHA or GRAPHICS button to select the screen
which you'd  -"
150       PRINT TABXY(10,11);"like to see."
160       PRINT CHR$(129)
170       PRINT TABXY(15,18);" WHEN YOU ARE READY,PLEASE PRESS THE 'CONTINUE' KE
Y. "
180       PAUSE
190       PRINT CHR$(12)
200       PRINT CHR$(128)
210       PRINT TABXY(10,6);"Please choose the progras which you'd like to use,b
y press the -"
220       PRINT TABXY(10,7);"number of the option.
            "
230       PRINT CHR$(132)
240       PRINT TABXY(21,9);"Option.";TABXY(51,9);"Program."
250       PRINT CHR$(128)
260       PRINT TABXY(10,11);"           1                    C-V Measureae
nt.              "
270       PRINT TABXY(10,12);"           2                    Recall C-V Ch
aracteristics data."
280       PRINT TABXY(10,13);"           3                    RESISTANCE Me
asureaent.       "
```

```
290       PRINT TABXY(10,14);"          4                    Recall RESIST
ANCE data.          "
300       PRINT TABXY(10,15);"          5                    MOSFET's thre
shold voltage.      "
310       PRINT TABXY(10,16);"          6                    EXIT
                    "
320       BEEP
330       INPUT Op
340       IF Op<1 OR Op>6 THEN 330
350       ON Op GOTO 360,390,420,450,480,510
360       PRINT CHR$(129)
370       PRINT TABXY(22,11);" 1 "
380       LOAD "DHA"
390       PRINT CHR$(129)
400       PRINT TABXY(22,12);" 2 "
410       LOAD "DHA10"
420       PRINT CHR$(129)
430       PRINT TABXY(22,13);" 3 "
440       LOAD "RESIST"
450       PRINT CHR$(129)
460       PRINT TABXY(22,14);" 4 "
470       LOAD "RESIST_OUT"
480       PRINT CHR$(129)
490       PRINT TABXY(22,15);" 5 "
500       LOAD "MOS_T1"
510       PRINT CHR$(129)
520       PRINT TABXY(22,16);" 6 "
530       END
```

```
10                              !!!!!!!!!!!!!!!!!!
20                              !! MAIN PROGRAM !!
30                              !!    "DHA"     !!
40                              !!!!!!!!!!!!!!!!!!
50      ! V(*) is the array keeping the values of voltage data.
60      ! C(*) is the array keeping the values of capacitance data.
70      ! G(*) is the array keeping the values of conductance data.
80      ! D(*) is the array keeping the values of dispation factor data.
90      ! Op   is the variable keeping the code number for choosing the mode of -
100     !         operation.
110                             !------------------!
120     COM V(700),C(700),G(700),D(700)
130     COM REAL K1,K2,Y,C$[5],K$[5]
140     COM REAL Amax,Amin,Bmax,Bmin,Vcmax,Vcmin,Vgmax,Vgmin,INTEGER I,J,Op
150                             !------------------!
160     PRINT CHR$(12)
170     PRINT CHR$(129)
180     PRINT TABXY(10,9);"PLEASE SELECT THE OPTION BY PRESS THE DESIRE NUMBER &
ENTER KEY."
190     PRINT TABXY(30,11);"1. MOS MEASUREMENT."
200     PRINT TABXY(30,13);"2. MOS ANALYSIS.   "
210     INPUT Op
220     IF Op<>1 AND Op<>2 THEN 210
230     IF Op=1 THEN
240        LOADSUB Set_cond FROM "DHA1"
250        Set_cond
260        ELSE
270        LOADSUB Analyse_data FROM "DHA8"
280        Analyse_data
290        GOTO 570
300     END IF
310     IF C$="X" THEN 570
320     LOADSUB Measure FROM "DHA5"
330     Measure
340     PRINT CHR$(12)
350     PRINT CHR$(131)
360     PRINT TABXY(10,10);" Would you like to save the data on disk ? (yes or no
) "
370     INPUT P$
380     IF P$<>"Y" AND P$<>"y" AND P$<>"N" AND P$<>"n" THEN 370
390     IF P$="Y" OR P$="y" THEN
400        LOADSUB Record FROM "DHA14"
410        Record
420        ELSE
430        GOTO 440
440     END IF
450     PRINT CHR$(12)
460     PRINT CHR$(131)
470     PRINT TABXY(1,10);"Would you like to analyse the impotant parameter of MO
S cap.? ((Y)es or (N)o)."
480     INPUT P$
490     IF P$<>"Y" AND P$<>"y" AND P$<>"N" AND P$<>"n" THEN 480
500     IF P$="Y" OR P$="y" THEN
510        LOADSUB Analyse_data FROM "DHA8"
520        Analyse_data
530        ELSE
540        GOTO 550
550     END IF
560     LOAD "MENU"
570     END
```

```
10                      !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
20                      !! MOS MEASUREMENT PROGRAM !!
30                      !!          "DHA1"          !!
40                      !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
50      SUB Set_cond
60      ! K1,K2 are the set value of starting and final voltage,      -
70      !       respectively,which the user want to choose,in range -32
80      !       to 32 volts.
90      ! Y     is the constant value for stepping up or down the gate-
100     !       voltage.
110     ! C$    keeps the frequency code to control the multi-frequency
120     !       LCR meter.
130     ! K$    keeps the code to choose the measured parameter from LCR meter.
140                             !---------------------!
150       COM V(*),C(*),G(*),D(*)
160       COM REAL K1,K2,Y,C$,K$
170       COM REAL Amax,Amin,Bmax,Bmin,Vcmax,Vcmin,Vgmax,Vgmin,INTEGER I,J,Op
180                             !---------------------!
190       PRINT CHR$(12)
200       PRINT CHR$(131)
210       PRINT TABXY(10,10);" Please connect your sample following this connect
ion.      "
220       PRINT TABXY(10,11);" Metal oxide contact is connected to high terminal
 of 4274A."
230       PRINT TABXY(10,12);" Substrate contact is connected to low terminal of
 4274A.   "
240       PRINT CHR$(129)
250       PRINT TABXY(20,14);" Press continue key when you are ready. "
260       PAUSE
270                               !------------------!
280       PRINT CHR$(12)
290       PRINT CHR$(128)
300       PRINT TABXY(15,5);"ENTER VALUE STARTING VOLTAGE IN RANGE -32 TO 32."
310       INPUT K1
320       IF K1<-32 OR K1>32 THEN
330          PRINT TABXY(15,7);"DON'T BE SILLY,PLEASE GIVE THE VOLTAGE IN RANGE
-32 TO 32."
340          WAIT 3
350          PRINT TABXY(15,7);"
             "
360          GOTO 310
370       END IF
380       PRINT CHR$(129)
390       PRINT TABXY(20,10);" STARTING VOLTAGE = ",K1," V. "
400       IF K1>0 THEN
410          Y=.2
420          ELSE
430          Y=-.2
440       END IF
450       PRINT CHR$(128)
460       PRINT TABXY(15,5);"ENTER THE VALUE OF FINAL VOLTAGE IN RANGE -32 TO 32
."
470       INPUT K2
480       IF K2<-32 OR K2>32 THEN
490          PRINT TABXY(15,7);"DON'T BE SILLY,PLEASE GIVE THE VOLTAGE IN RANGE
-32 TO 32."
```

```
500         WAIT 3
510         PRINT TABXY(15,7);"
          "
520         GOTO 470
530       END IF
540       PRINT CHR$(129)
550       PRINT TABXY(20,11);" FINAL VOLTAGE    = ",K2," V. "
560       PRINT CHR$(128)
570       PRINT TABXY(15,5);"
 "
580                          !------------------!
590       WAIT 3
600       PRINT CHR$(12)
610       PRINT CHR$(128)
620       PRINT TABXY(7,10);"PLEASE CHOOSE THE FOLLOWING FREQUENCY CODE WHICH YO
U WANT TO OPERATE."
630       PRINT CHR$(129)
640       PRINT TABXY(15,12);"   F11 FOR 100 Hz.        F17 FOR 4 KHz.          "
650       PRINT TABXY(15,13);"   F12 FOR 120 Hz.        F18 FOR 10 KHz.         "
660       PRINT TABXY(15,14);"   F13 FOR 200 Hz.        F19 FOR 20 KHz.         "
670       PRINT TABXY(15,15);"   F14 FOR 400 Hz.        F20 FOR 40 KHz.         "
680       PRINT TABXY(15,16);"   F15 FOR 1   KHz.       F21 FOR 100 KHz.        "
690       PRINT TABXY(15,17);"   F16 FOR 2   KHz.       X TO EXIT THE PROGRAM.  "
700       INPUT C$
710       IF C$="X" THEN
720          BEEP
730          GOTO 880
740          ELSE
750          OUTPUT 717;C$
760       END IF
770                          !------------------!
780       PRINT CHR$(12)
790       PRINT CHR$(129)
800       PRINT TABXY(10,10);" If you want to measure C/G characteristic,press A
"
          "
810       PRINT TABXY(10,11);" If you want to measure C/D characteristic,press a
ny key. "
820       INPUT K$
830       IF K$="A" THEN
840          OUTPUT 717;"A2B3"
850          ELSE
860          OUTPUT 717;"A2B1"
870       END IF
880    SUBEND
```

```
10                      !!!!!!!!!!!!!!!!!!!!!!!!
20                      !! INPUT DATA PROGRAM !!
30                      !!      "DHA2"        !!
40                      !!!!!!!!!!!!!!!!!!!!!!!!
50    SUB Input
60    ! X           is each voltage value stepped up and down by Y.
70    ! I,J         are the counters of set of input data.
80    ! A,B,Amax,Amin,Bmax,Bmin,Vmax1,Vmax2,Vmin1,Vmin2 are the dummy
90    !             variables.
100   ! Vcmax,Vcmin are the values of voltage which capacitance is  -
110   !             maximum and minimum,respectively.
120   ! Vgmax,Vgmin are the values of voltage which conductance is  -
130   !             maximum and minimum,respectively.
140   ! Vdmax,Vdmin are the values of voltage which dispation factor-
150   !             is maximum and minimum,respectively.
160   ! F$          keeps the name of data file which is created.
170   ! L           is the variable to point each set of data keeped in files.
180   ! Msi         is the variable to keep the number of mass storage.
190                       !-------------------!
200      COM V(*),C(*),G(*),D(*)
210      COM REAL K1,K2,Y,C$,K$
220      COM REAL Amax,Amin,Bmax,Bmin,Vcmax,Vcmin,Vgmax,Vgmin,INTEGER I,J,Op
230                       !-------------------!
240      PRINT CHR$(131)
250      PRINT TABXY(10,15);" Please wait a moment,program is running. "
260      FOR X=0 TO K1 STEP Y
270         OUTPUT 717;"BI";VAL$(X);"E";"00V";
280         WAIT .2
290      NEXT X
300                       !-------------------!
310      I=0
320      FOR X=K1 TO K2 STEP -Y
330         I=I+1
340         OUTPUT 717;"BI";VAL$(X);"E";"00V";
350         WAIT .2
360         ENTER 717;A,B
370         IF X=K1 THEN
380            Amax=A
390            Bmax=B
400            Vmax1=X
410            Vmax2=X
420            Amin=A
430            Bmin=B
440            Vmin1=X
450            Vmin2=X
460         END IF
470         IF A>Amax THEN
480            Amax=A
490            Vmax1=X
500         END IF
510         IF A<Amin THEN
520            Amin=A
530            Vmin1=X
540         END IF
550         IF B>Bmax THEN
```

```
560             Bmax=B
570             Vmax2=X
580          END IF
590          IF B<Bmin THEN
600             Bmin=B
610             Vmin2=X
620          END IF
630          V(I)=X
640          C(I)=A
650          Vcmax=Vmax1
660          Vcmin=Vmin1
670          IF K$="A" THEN
680             G(I)=B
690             Vgmax=Vmax2
700             Vgmin=Vmin2
710             ELSE
720             D(I)=B
730             Vdmax=Vmax2
740             Vdmin=Vmin2
750          END IF
760       NEXT X
770       J=1
780       FOR X=K2 TO K1 STEP Y
790          J=J+1
800          OUTPUT 717;"BI";VAL$(X);"E";"00V";
810          WAIT .2
820          ENTER 717;A,B
830          V(J)=X
840          C(J)=A
850          IF K$="A" THEN
860             G(J)=B
870             ELSE
880             D(J)=B
890          END IF
900       NEXT X
910       REDIM V(J),C(J),G(J),D(J)
920                        !-----------------!
930       FOR X=K1 TO 0 STEP -Y
940          OUTPUT 717;"BI";VAL$(X);"E";"00V";
950          WAIT .2
960       NEXT X
970    SUBEND
```

```
10                      !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
20                      !! SCALING AND DRAW X-Y AXIS !!
30                      !!      IN LINEAR SCALE      !!
40                      !!          "DHA3"           !!
50                      !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
60      SUB Scaling
70      ! Wl,Wr,Wb,Wt       are the variables setting the reference of scailing.
80      ! Cal,Car,Cab,Cat   are the variables setting the boundary of axes.
90      ! Cfl,Cfr,Cfb,Cft   are the variables setting the boundary of graphics.
100     ! Xmax_gdu,Ymax_gdu are the parameter of screen
110     ! Xtick,Ytick,Xlocy |
120     ! Ylocx,Xmajor,Size > are the parameters of the 'AXES' statement.
130     ! Ymajor            |
140     ! M                 is the dummy variable.
150                           !--------------------!
160       COM V(*),C(*),G(*),D(*)
170       COM REAL K1,K2,Y,C$,K$
180       COM REAL Amax,Amin,Bmax,Bmin,Vcmax,Vcmin,Vgmax,Vgmin,INTEGER I,J,Op
190                           !--------------------!
200       Amaxx=Amax*10^12                        ! Maximum value of the MOS CAP.
210       Aminx=Amin*10^12                        ! Minimum value of the MOS CAP.
220       Xmax_gdu=100*RATIO                      !\ Set parameter of screen.
230       Ymax_gdu=100                            !/
240       Ylocx=20*INT(Aminx/20)                  ! Find pos. of X-axis on Y-axis.
250       Wl=MIN(K1,K2)-10                        !\
260       Wr=MAX(K1,K2)+10                        ! \ Set relative boundary.
270       Wb=Ylocx-40                             ! /
280       Wt=Amaxx*1.2                            !/
290       Cal=Wl+5                                !\
300       Car=Wr-5                                ! \ Set parameter of soft clip.
310       Cab=Ylocx                               ! /
320       Cat=Amaxx*1.1                           !/
330       Cfl=Cal-2                               !\
340       Cfr=Car+2                               ! \ Set parameter of frame.
350       Cfb=Ylocx-30                            ! /
360       Cft=Amaxx*1.15                          !/
370       Xtick=1                                 !\
380       Ytick=10                                ! \
390       Xlocy=0                                 !  \ Set parameter of axis.
400       Xmajor=5                                !  /
410       Ymajor=5                                ! /
420       Size=3                                  !/
430                     !-----------------!
440       GINIT
450       DEG
460       GRAPHICS ON
470       LORG 5                                        !\
480       CSIZE 5                                       ! \
490       MOVE Xmax_gdu/2,.98*Ymax_gdu                  ! |
500       LABEL "C-V CHARACTERISTICS"                   ! |
510       CSIZE 4                                       ! |
520       MOVE Xmax_gdu/2,.93*Ymax_gdu                  ! |
530       IF C$="F11" THEN LABEL "Measure at 100 Hz"    ! |
540       IF C$="F12" THEN LABEL "Measure at 120 Hz"    !  \
550       IF C$="F13" THEN LABEL "Measure at 200 Hz"    !   > Label head of graph.
```

```
560       IF C$="F14" THEN LABEL "Measure at 400 Hz" !  /
570       IF C$="F15" THEN LABEL "Measure at 1 KHz"  ! |
580       IF C$="F16" THEN LABEL "Measure at 2 KHz"  ! |
590       IF C$="F17" THEN LABEL "Measure at 4 KHz"  ! |
600       IF C$="F18" THEN LABEL "Measure at 10 KHz" ! |
610       IF C$="F19" THEN LABEL "Measure at 20 KHz" ! |
620       IF C$="F20" THEN LABEL "Measure at 40 KHz" ! /
630       IF C$="F21" THEN LABEL "Measure at 100 KHz"!/
640       VIEWPORT .02*Xmax_gdu,.98*Xmax_gdu,.02*Ymax_gdu,.9*Ymax_gdu!\
650       WINDOW Wl,Wr,Wb,Wt                                          ! |
660       CLIP Cal,Car,Cab,Cat                                        !  \
670       AXES Xtick,Ytick,Xlocy,Ylocx,Xmajor,Ymajor,Size             !   > Line.
680       CLIP OFF                                                    !  /  scale
690       CLIP Cfl,Cfr,Cfb,Cft                                        ! |
700       FRAME                                                       !/
710                          !------------------!
720       LORG 7                              !\
730       FOR M=Ylocx TO Cat STEP 50          ! \
740          MOVE Xlocy,M                     !  \
750          CSIZE 4,.4                       !   \
760          LABEL M                          !    \ Label Y-axis.
770       NEXT M                              !    /
780       MOVE 0,Cat                          !   /
790       IMOVE -3,0                          !  /
800       LDIR 90                             ! /
810       LABEL "CAPACITANCE  (pF)"           !/
820       LORG 6                              !\
830       LDIR 360                            ! \
840       FOR M=Cal TO Car STEP 1             !  \
850          MOVE M,Ylocx                     !   \
860          IF M MOD 5=0 THEN LABEL M        !    > Label X-axis.
870       NEXT M                              !   /
880       LORG 5                              !  /
890       IMOVE -5,-10                        ! /
900       LABEL "VOLTAGE  (V)"                !/
910    SUBEND
```

```
10                              !!!!!!!!!!!!!!!!!!!!
20                              !!   PLOT PROGRAM  !!
30                              !! IN LINEAR SCALE !!
40                              !!    "DHA4"       !!
50                              !!!!!!!!!!!!!!!!!!!!
60      SUB Plot_linear
70      ! O     is the pointer variable.
80      ! P$    is the variable to keep the answer string.
90                              !---------------!
100       COM V(*),C(*),G(*),D(*)
110       COM REAL K1,K2,Y,C$,K$
120       COM REAL Amax,Amin,Bmax,Bmin,Vcmax,Vcmin,Vgmax,Vgmin,INTEGER I,J,Op
130       DIM Cx(700)
140                             !---------------!
150       GRAPHICS ON
160       Cx(1)=C(1)*10^12                !\
170       MOVE V(1),Cx(1)                 ! \
180       DRAW V(1),Cx(1)                 !  \
190       FOR O=2 TO I                    !   > Plot cuvre with increasing volt.
200          Cx(O)=C(O)*10^12             !  /
210          DRAW V(O),Cx(O)              ! /
220       NEXT O                          !/
230       FOR O=I+1 TO J                  !\
240          Cx(O)=C(O)*10^12             ! \ Plot cuvre with decreasing voltage.
250          DRAW V(O),Cx(O)              ! /
260       NEXT O                          !/
270                             !-----------------!
280       PRINT CHR$(12)
290       PRINT CHR$(129)
300       PRINT TABXY(10,10);" Would you like to have a paper of your C/V curve
? (y or n) "
310       INPUT P$
320       IF P$<>"Y" AND P$<>"y" AND P$<>"N" AND P$<>"n" THEN 310
330       IF P$="N" OR P$="n" THEN 470
340       PRINT TABXY(10,10);" If you would like to print the curve by printer,p
lease press key 'A'. "
350       PRINT TABXY(10,11);" If you would like to plot the curve by plotter,pl
ease press any key.  "
360       INPUT Pr$
370       IF Pr$="A" THEN
380          PRINT CHR$(131)
390          PRINT TABXY(25,16);" PRINTER IS READY,PRESS CONTINUE KEY "
400          PAUSE
410          PRINT CHR$(12)
420          DUMP GRAPHICS #701
430          ELSE
440          LOADSUB Plotter FROM "DHA10"
450          Plotter
460          PRINT CHR$(12)
470       END IF
480     GRAPHICS OFF
490     SUBEND
```

```
10                      !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
20                      !! C-V AND G-V MEASUREMENT !!
30                      !!         "DHA5"         !!
40                      !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
50    SUB Measure
60                           !-----------------!
70       COM V(*),C(*),G(*),D(*)
80       COM REAL K1,K2,Y,C$,K$
90       COM REAL Amax,Amin,Bmax,Bmin,Vcmax,Vcmin,Vgmax,Vgmin,INTEGER I,J,Op
100                          !-----------------!
110      LOADSUB Input FROM "DHA2"              !\ Input data from LCR meter.
120      Input                                  !/
130      IF K$="A" THEN
140         PRINT CHR$(12)
150         PRINT CHR$(129)
160         PRINT TABXY(10,10);" IF YOU WANT TO SEE C-V CURVE,PLEASE PRESS ";CH
R$(131);"'C'";CHR$(129);" KEY "
170         PRINT TABXY(10,11);"
   "
180         PRINT TABXY(10,12);" IF YOU WANT TO SEE G-V CURVE;PLEASE PRESS ";CH
R$(131);"ANY";CHR$(129);" KEY "
190         ELSE
200         PRINT CHR$(12)
210         PRINT CHR$(129)
220         PRINT TABXY(10,10);" IF YOU WANT TO SEE C-V CURVE,PLEASE PRESS ";CH
R$(131);"'C'";CHR$(129);" KEY "
230         PRINT TABXY(10,11);"
   "
240         PRINT TABXY(10,12);" IF YOU WANT TO SEE D-V CURVE;PLEASE PRESS ";CH
R$(131);"ANY";CHR$(129);" KEY "
250      END IF
260      INPUT T$
270      IF T$="C" THEN
280         LOADSUB Scaling FROM "DHA3"        !\
290         LOADSUB Plot_linear FROM "DHA4"    ! \ Plot data in linear scale.
300         Scaling                            ! /
310         Plot_linear                        !/
320         PRINT CHR$(12)
330         PRINT CHR$(129)
340         PRINT TABXY(10,10);"Would you like to see another curve ? ((Y)es or
 (N)o."
350         INPUT P$
360         IF P$<>"Y" AND P$<>"y" AND P$<>"N" AND P$<>"n" THEN 350
370         IF P$="Y" OR P$="y" THEN
380            PRINT CHR$(129)
390            PRINT TABXY(10,12);" Would you like to see G-V curve in ";CHR$(1
31);"(S)";CHR$(129);"emilog or ";CHR$(131);"(L)";CHR$(129);"inear scale ? "
400            INPUT W$
410            IF W$<>"S" AND W$<>"s" AND W$<>"L" AND W$<>"l" THEN 400
420            IF W$="S" OR W$="s" THEN
430               LOADSUB Semilog FROM "DHA6"    !\
440               LOADSUB Plot_semi FROM "DHA7"  ! \ Plot data in semilog
450               Semilog                        ! / scale.
460               Plot_semi                      !/
470               PRINT TABXY(10,14);" Would you like to see G-V curve in linea
r scale ? (Y)es or (N)o. "
```

```
480               INPUT P$
490               IF P$<>"Y" AND P$<>"y" AND P$<>"N" AND P$<>"n" THEN 480
500               IF P$="Y" OR P$="y" THEN
510                  LOADSUB Scaling_con FROM "DHA11"      !\
520                  LOADSUB Plot_linear_con FROM "DHA12"  ! \ Plot data in
530                  Scaling_con                           ! / linear scale.
540                  Plot_linear_con                       !/
550                  ELSE
560                  GOTO 570
570               END IF
580               ELSE
590               LOADSUB Scaling_con FROM "DHA11"      !\
600               LOADSUB Plot_linear_con FROM "DHA12"  ! \ Plot data in linear
610               Scaling_con                           ! / scale.
620               Plot_linear_con                       !/
630               PRINT TABXY(10,14);" Would you like to see G-V curve in semil
og scale ? (Y)es or (N)o. "
640               INPUT P$
650               IF P$<>"Y" AND P$<>"y" AND P$<>"N" AND P$<>"n" THEN 640
660               IF P$="Y" OR P$="y" THEN
670                  LOADSUB Semilog FROM "DHA6"    !\
680                  LOADSUB Plot_semi FROM "DHA7"  ! \ Plot data in semilog
690                  Semilog                        ! / scale.
700                  Plot_semi                      !/
710                  ELSE
720                  GOTO 730
730               END IF
740            END IF
750            ELSE
760            GOTO 770
770         END IF
780         ELSE
790         PRINT CHR$(12)
800         PRINT CHR$(129)
810         PRINT TABXY(10,12);" Would you like to see G-V curve in ";CHR$(131)
;"(S)";CHR$(129);"emilog or ";CHR$(131);"(L)";CHR$(129);"inear scale ? "
820         INPUT W$
830         IF W$<>"S" AND W$<>"s" AND W$<>"L" AND W$<>"l" THEN 820
840         IF W$="S" OR W$="s" THEN
850            LOADSUB Semilog FROM "DHA6"      !\
860            LOADSUB Plot_semi FROM "DHA7"    ! \ Plot data in semi-log
870            Semilog                          ! / scale.
880            Plot_semi                        !/
890            PRINT TABXY(10,14);" Would you like to see G-V curve in linear s
cale ? (Y)es or (N)o. "
900            INPUT P$
910            IF P$<>"Y" AND P$<>"y" AND P$<>"N" AND P$<>"n" THEN 900
920            IF P$="Y" OR P$="y" THEN
930               LOADSUB Scaling_con FROM "DHA11"
940               LOADSUB Plot_linear_con FROM "DHA12"
950               Scaling_con
960               Plot_linear_con
970               ELSE
980               GOTO 990
990            END IF
```

```
1000            ELSE
1010            LOADSUB Scaling_con FROM "DHA11"      !\
1020            LOADSUB Plot_linear_con FROM "DHA12"  ! \ Plot data in linear
1030            Scaling_con                           ! / scale.
1040            Plot_linear_con                       !/
1050            PRINT TABXY(10,14);" Would you like to see G-V curve in semilog
scale ? (Y)es or (N)o. "
1060            INPUT P$
1070            IF P$<>"Y" AND P$<>"y" AND P$<>"N" AND P$<>"n" THEN 1060
1080            IF P$="Y" OR P$="y" THEN
1090               LOADSUB Semilog FROM "DHA6"
1100               LOADSUB Plot_semi FROM "DHA7"
1110               Semilog
1120               Plot_semi
1130               ELSE
1140               GOTO 1150
1150            END IF
1160         END IF
1170         PRINT CHR$(12)
1180         PRINT TABXY(10,10);" Would you like to see another curve ? ((Y)es o
r (N)o. "
1190         INPUT P$
1200         IF P$<>"Y" AND P$<>"y" AND P$<>"N" AND P$<>"n" THEN 1190
1210         IF P$="Y" OR P$="y" THEN
1220            LOADSUB Scaling FROM "DHA3"        !\
1230            LOADSUB Plot_linear FROM "DHA4"    ! \ Plot data in linear scale.
1240            Scaling                            ! /
1250            Plot_linear                        !/
1260            ELSE
1270            GOTO 1280
1280         END IF
1290      END IF
1300   SUBEND
```

```
10                      !!!!!!!!!!!!!!!!!!!!!!!!!!!!
20                      !! SCALING AND DRAW AXIS !!
30                      !!   IN SEMI-LOG SCALE   !!
40                      !!        "DHA6"         !!
50                      !!!!!!!!!!!!!!!!!!!!!!!!!!!!
60    SUB Semilog
70    ! Bmaxl,Bminl   are the variables to keep the logalithm value.
80    ! Bmaxli,Bminli are the variables to keep the integer value of the      -
90    !               logarithm value.
100   ! Xran          is the variable to keep the X-axis range.
110   ! Yran          is the variable to keep the Y-axis range.
120   ! Xdiv          is the variable to keep each division on X-axis.
130   ! Ydiv          is the variable to keep each division on Y-axis.
140   ! O,R           are the dummy variables.
150   ! Wl,Wr,Wb,Wt   are the variables setting the reference of scailing.
160   ! Xlocy,Ylocx   are the parameters of the 'AXES' statement.
170                     !--------------------!
180     COM V(*),C(*),G(*),D(*)
190     COM REAL K1,K2,Y,C$,K$
200     COM REAL Amax,Amin,Bmax,Bmin,Vcmax,Vcmin,Vgmax,Vgmin,INTEGER I,J,Op
210                     !--------------------!
220     Bmaxx=ABS(Bmax*10^9)                  ! Maximum conductance value.
230     Bminx=ABS(Bmin*10^9)                  ! Minimum conductance value.
240     Bmaxl=LGT(Bmaxx)                     !\
250     Bminl=LGT(Bminx)                     ! \ Find order of conductance value
260     Bmaxli=INT(Bmaxl)                    ! / in nanosemen.
270     Bminli=INT(Bminl)                    !/
280     Xmax_gdu=100*RATIO                   !\ Set parameter of screen.
290     Ymax_gdu=100                         !/
300     Wl=MIN(K1,K2)                        !\
310     Wr=MAX(K1,K2)                        ! \
320     Wb=Bminli                            !  \
330     IF FRACT(Bmaxl)=0 THEN               !   \
340       Wt=Bmaxli                          !    \ Set relative boundary.
350       Yran=Bmaxli-Bminli                 !    /
360       ELSE                               !   /
370       Wt=Bmaxli+1                        !  /
380       Yran=Bmaxli-Bminli+1               ! /
390     END IF                               !/
400     Xran=MAX(K1,K2)-MIN(K1,K2)
410     Xdiv=.83*Xmax_gdu/Xran
420     Ydiv=.75*Ymax_gdu/Yran
430     Xlocy=Wb
440     Ylocx=Wl
450     GINIT
460     DEG
470     GRAPHICS ON
480     LORG 5                                    !\
490     CSIZE 5                                   ! \
500     MOVE Xmax_gdu/2,.98*Ymax_gdu              !  |
510     LABEL "G-V CHARACTERISTICS"               !  |
520     CSIZE 4                                   !  |
530     MOVE Xmax_gdu/2,.93*Ymax_gdu              !  |
540     IF C$="F11" THEN LABEL "Measure at 100 Hz" !  |
550     IF C$="F12" THEN LABEL "Measure st 120 Hz" !   \
```

```
560       IF C$="F13" THEN LABEL "Measure at 200 Hz" !    > Label head of graph.
570       IF C$="F14" THEN LABEL "Measure at 400 Hz" !   /
580       IF C$="F15" THEN LABEL "Measure at 1 KHz"  !  |
590       IF C$="F16" THEN LABEL "Measure at 2 KHz"  !  |
600       IF C$="F17" THEN LABEL "Measure at 4 KHz"  !  |
610       IF C$="F18" THEN LABEL "Measure at 10 KHz" !  |
620       IF C$="F19" THEN LABEL "Measure at 20 KHz" !  |
630       IF C$="F20" THEN LABEL "Measure at 40 KHz" ! /
640       IF C$="F21" THEN LABEL "Measure at 100 KHz"!/
650       MOVE Xmax_gdu/2,.03*Ymax_gdu                !\
660       LABEL "GATE VOLTAGE (V)"                    ! \
670       CSIZE 3                                     !  \
680       FOR R=0 TO Xran                             !   > Label X-axis.
690          MOVE .15*Xmax_gdu+(R*Xdiv),.1*Ymax_gdu   !  /
700          LABEL MIN(K1,K2)+R                       ! /
710       NEXT R                                      !/
720       LDIR 90                                     !\
730       CSIZE 4                                     ! \
740       MOVE .01*Xmax_gdu,Ymax_gdu/2                ! |
750       LABEL "CONDUCTANCE (ns)"                    ! |
760       LDIR 0                                      ! |
770       CSIZE 3                                     ! |
780       FOR R=0 TO Yran                             ! |
790          MOVE 14,.15*Ymax_gdu+(R*Ydiv)            ! |
800          IF Bminli+R=0 THEN                       ! |
810             LABEL "0"                             ! |
820             ELSE                                  !  \
830             LABEL "10"                            !   > Label Y-axis.
840          END IF                                   !  /
850       NEXT R                                      ! |
860       FOR R=0 TO Yran                             ! |
870          MOVE 15,.15*Ymax_gdu+(R*Ydiv)+2          ! |
880          IF Bminli+R=0 THEN                       ! |
890             LABEL " "                             ! |
900             ELSE                                  ! |
910             LABEL "  ";Bminli+R                   ! |
920          END IF                                   ! /
930       NEXT R                                      !/
940       VIEWPORT .15*Xmax_gdu,.98*Xmax_gdu,.15*Ymax_gdu,.9*Ymax_gdu !\
950       WINDOW Wl,Wr,Wb,Wt                          ! \
960       AXES 1,1,Xlocy,Ylocx                        ! |
970       GRID 1,1,0,0                                ! |
980       PRINT CHR$(12)
990       PRINT CHR$(128)
1000      PRINT TABXY(0,10);"Would you like to draw the line between each order
of the scale ? ";CHR$(130);"Y";CHR$(128);"es OR ";CHR$(130);"N";CHR$(128);"o."
1010      INPUT P$
1020      IF P$<>"Y" AND P$<>"y" AND P$<>"N" AND P$<>"n" THEN 1010
1030      IF P$="N" OR P$="n" THEN 1110
1040      FOR D=Bminli TO Bmaxli                      !  \ Semi-
1050         FOR R=2 TO 9                             !   > log
1060            Y=D+LGT(R)                            !  / scale
1070            MOVE MIN(K1,K2),Y                     ! |
1080            DRAW MAX(K1,K2),Y                     ! |
1090         NEXT R                                   ! /
1100      NEXT D                                      !/
1110   SUBEND
```

```
10                          !!!!!!!!!!!!!!!!!!!!!!!
20                          !!    PLOT PROGRAM   !!
30                          !! IN SEMI-LOG SCALE !!
40                          !!      "DHA7"       !!
50                          !!!!!!!!!!!!!!!!!!!!!!!
60      SUB Plot_semi
70      ! S    is the dummy variable.
80                          !--------------------!
90        COM V(*),C(*),G(*),D(*)
100       COM REAL K1,K2,Y,C$,K$
110       COM REAL Amax,Amin,Bmax,Bmin,Vcmax,Vcmin,Vgmax,Vgmin,INTEGER I,J,Op
120       DIM Gx(700)
130                         !--------------------!
140       GRAPHICS ON
150       Gx(1)=LGT(ABS(G(1)*10^9))
160       MOVE V(1),Gx(1)                  !\
170       DRAW V(1),Gx(1)                  ! \
180       FOR S=2 TO I                     !  \ Plot data with increasing voltage
190         Gx(S)=LGT(ABS(G(S)*10^9))      !  /
200         DRAW V(S),Gx(S)                ! /
210       NEXT S                           !/
220       FOR S=I+1 TO J                   !\
230         Gx(S)=LGT(ABS(G(S)*10^9))      ! \ Plot data with decreasing voltage
240         DRAW V(S),Gx(S)                ! /
250       NEXT S                           !/
260                         !--------------------!
270       PRINT CHR$(12)
280       PRINT CHR$(129)
290       PRINT TABXY(10,10);" Would you like to have a paper of your G/V curve
? (y or n) "
300       INPUT P$
310       IF P$<>"Y" AND P$<>"y" AND P$<>"N" AND P$<>"n" THEN 300
320       IF P$="N" OR P$="n" THEN 460
330       PRINT TABXY(10,10);" If you would like to print the curve by printer,p
lease press key 'A'. "
340       PRINT TABXY(10,11);" If you would like to plot the curve by plotter,pl
ease press any key. "
350       INPUT Pr$
360       IF Pr$="A" THEN
370         PRINT CHR$(131)
380         PRINT TABXY(25,16);" PRINTER IS READY,PRESS CONTINUE KEY "
390         PAUSE
400         PRINT CHR$(12)
410         DUMP GRAPHICS #701
420         ELSE
430         LOADSUB Plotter FROM "DHA9"
440         Plotter
450         PRINT CHR$(12)
460       END IF
470     GRAPHICS OFF
480     SUBEND
```

```
10                      !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
20                      !! MOS CAPACITANCE ANALYSIS !!
30                      !!          "DHAB"          !!
40                      !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
50    SUB Analyse_data
60    ! St$       is the variable to keep the substrate's type.
70    ! Ga$       is the variable to keep the gate area's shape.
80    ! Di        is the variable to keep the gate area's diameter.
90    ! W         is the variable to keep the gate area's width.
100   ! L         is the variable to keep the gate area's length.
110   ! Ag        is tha variable to keep the gate area.
120   ! Dox       is the variable to keep the gate oxide's thickness.
130   ! N         is the variable to keep the first assumption of substrate's -
140   !           concentration.
150   ! Csmin     is the variable to keep the minimum depletion region of cap.-
160   !           when the surface of substrate is inverted.
170   ! Ncon      is tha variable to keep the substrate's concentration.
180   ! Cfbs      is the variable to keep the silicon surface capacitance at  -
190   !           flatband in Farad.
200   ! Cfb       is the variable to keep the flatband capacitance in Farad.
210   ! Vfb1,Vfb2 is the variable to keep the flatband voltage in forward and -
220   !           backward ways,respectively.
230   ! Vfb       is the variable to keep the flatband voltage.
240   ! Mt        is tha variable to keep the type number of the gate metal.
250   ! Wfm       is the variable to keep the vacuum work function of the gate
260   !           metal.
270   ! Wms       is the variable to keep the work function difference between
280   !           the gate metal and the semiconductor substrate.
290   ! Ci        is the variable to keep the oxide capacitance per unit area -
300   !           in Farad/cm2.
310   ! Dss       is the variable to keep the interfacial state density.
320                     !---------------------!
330      COM V(*),C(*),G(*),D(*)
340      COM REAL K1,K2,Y,C$,K$
350      COM REAL Amax,Amin,Bmax,Bmin,Vcmax,Vcmin,Vgmax,Vgmin,INTEGER I,J,Op
360                     !---------------------!
370      T=300                    ! Room temperature in Kelvin.
380      Kb=1.38E-23              ! Boltzmaan constant.
390      Q=1.602E-19              ! Electron charge.
400      Ni=1.5E+10               ! Intrinsic concentration of Si at 300 K.
410      Eo=8.854E-14             ! Vacuum permittivity.
420      Eox=3.9                  ! SiO2 relative permittivity.
430      Es=11.7                  ! Si relative permittivity.
440      Eg=1.12                  ! Band gap energy of Si.
450      Eafs=4.23                ! Electron affinity of Si.
460          !-----------------------------------------------------!
470          ! Find type of substrate and the gate oxide's thickness. !
480          !-----------------------------------------------------!
490      IF Op=2 THEN
500         PRINT CHR$(12)
510         PRINT CHR$(131)
520         PRINT TABXY(1,1);"Please input the maximum capacitance (in pF)."
530         INPUT Amax
540         IF Amax<=0 THEN 530
550         PRINT TABXY(1,1);"Please input the minimum capacitance (in pF)."
```

```
560         INPUT Amin
570         IF Amin<=0 THEN 560
580         PRINT TABXY(1,1);"Please input type of substrate ((N)-type or (P)-t
ype)."
590         INPUT St$
600         IF St$<>"N" AND St$<>"n" AND St$<>"P" AND St$<>"p" THEN 590
610         ELSE
620         IF Vcmax<Vcmin THEN
630            St$="P"
640            ELSE
650            St$="N"
660         END IF
670      END IF
680      Cox=Amax
690      Cmin=Amin
700      PRINT CHR$(12)
710      PRINT CHR$(128)
720      PRINT TABXY(5,3);"Type of the sample substrate is ";St$;"-type."
730      PRINT TABXY(5,4);"Maximum capacitance,Cmax or Cox,is ";TAB(49);Cox*1.0
E+12;TAB(70);" pF"
740      PRINT TABXY(5,5);"Minimum capacitance,Cmin,is       ";TAB(49);Cmin*1.
0E+12;TAB(70);" pF"
750      PRINT CHR$(131)
760      PRINT TABXY(1,1);"Is your gate oxide layer SiO2 ? (yes(Y) or no(N)).
         "
770      INPUT P$
780      IF P$<>"Y" AND P$<>"y" AND P$<>"N" AND P$<>"n" THEN 770
790      IF P$="N" OR P$="n" THEN
800         PRINT CHR$(131)
810         PRINT TABXY(1,1);"Please input relative permittivity of oxide.
          "
820         INPUT Eox
830         IF Eox<=0 THEN 820
840      END IF
850      PRINT CHR$(128)
860      PRINT TABXY(5,6);"Relative permittivity of gate oxide is ";TAB(49);Eox
870      PRINT CHR$(131)
880      PRINT TABXY(1,1);"Do you know gate area ? (yes(Y) or no(N)).        "
890      INPUT P$
900      IF P$<>"Y" AND P$<>"y" AND P$<>"N" AND P$<>"n" THEN 890
910      IF P$="Y" OR P$="y" THEN 1100
920         PRINT TABXY(1,1);"Which shape is your sample's gate area ? ((C)ircl
e or (R)ectangle)."
930         INPUT Ga$
940         IF Ga$<>"C" AND Ga$<>"c" AND Ga$<>"R" AND Ga$<>"r" THEN 930
950         IF Ga$="C" OR Ga$="c" THEN
960            PRINT TABXY(1,1);"Please input your gate's diameter (in cm.)
                 "
970            INPUT Di
980            IF Di<=0 THEN 970
990            Ag=PI*(Di^2)/4
1000           ELSE
1010           PRINT TABXY(1,1);"Please input your rectangular gate's width (in
 cm.)
                 "
1020           INPUT W
```

```
1030            IF W<=0 THEN 1020
1040            PRINT TABXY(1,1);"Please input your rectangular gate's length (i
n cm.)
                    "
1050            INPUT L
1060            IF L<=0 THEN 1050
1070            Ag=W*L
1080          END IF
1090          GOTO 1130
1100        PRINT TABXY(1,1);"Please input your gate area (in cm2.)
                "
1110        INPUT Ag
1120        IF Ag<=0 THEN 1110
1130        PRINT CHR$(128)
1140        PRINT TABXY(5,7);"Gate area is ";TAB(49);Ag;TAB(70);" cm2"
1150        Dox=Eo*Eox*Ag/Cox
1160        PRINT TABXY(5,8);"Oxide layer thickness is ";TAB(49);Dox*1.0E+8;TAB(70
);" angst."
1170                !-------------------------------------!
1180                ! Find doping concentration of substrate. !
1190                !-------------------------------------!
1200        PRINT CHR$(131)
1210        PRINT TABXY(1,1);"Is your substrate Si ? ((Y)es or (N)o).
 "
1220        INPUT P$
1230        IF P$<>"Y" AND P$<>"y" AND P$<>"N" AND P$<>"n" THEN 1220
1240        IF P$="N" OR P$="n" THEN
1250           PRINT TABXY(1,1);"Please input relative permittivity of your substr
ate."
1260           INPUT Es
1270           IF Es<=0 THEN 1260
1280           PRINT TABXY(1,1);"Please input band gap energy of your substrate.
    "
1290           INPUT Eg
1300           IF Eg<=0 THEN 1290
1310           PRINT TABXY(1,1);"Please input electron affinity of your substrate.
    "
1320           INPUT Eafs
1330           IF Eafs<=0 THEN 1320
1340         END IF
1350         PRINT CHR$(128)
1360         PRINT TABXY(5,9);"Relative permittivity of substrate is ";TAB(49);Es
1370         N=1.0E+22
1380         Csmin=(Cox*Cmin)/(Cox-Cmin)
1390         Ncon=4*Kb*T*LOG(N/Ni)*(Csmin/Ag/Q)^2/Es/Eo
1400         IF (1-Ncon/N)<1.0E-4 THEN
1410            PRINT TABXY(5,10);"Doping concentration is ";TAB(49);Ncon;TAB(70);"
 /cm3"
1420            ELSE
1430            N=Ncon
1440            GOTO 1390
1450         END IF
1460                            !---------------------------!
1470                            ! Find flatband capacitance. !
1480                            !---------------------------!
1490        Cfbs=(Es*Eo*Q^2*Ncon/Kb/T)^(.5)
```

```
1500      PRINT TABXY(5,11);"Silicon surface capacitance per unit  -"
1510      PRINT TABXY(5,12);"area at flatband is ";TAB(49);Cfbs*1.0E+12;TAB(70);
" pF/cm2"
1520      Cfbs=Cfbs*Ag
1530      PRINT TABXY(5,13);"Silicon surface capacitance at flatband is ";TAB(49
);Cfbs*1.0E+12;TAB(70);" pF"
1540      Cfb=Cfbs*Cox/(Cfbs+Cox)
1550      PRINT TABXY(5,14);"Flatband capacitance is ";TAB(49);Cfb*1.0E+12;TAB(7
0);" pF"
1560                        !--------------------------!
1570                        ! Find the flatband voltage. !
15B0                        !--------------------------!
1590      IF C(I)>C(I) THEN                          !\
1600         Dd=1                                    ! \
1610         E=I                                     ! |
1620         F=1                                     ! |
1630         ELSE                                    ! |
1640         Dd=I                                    ! |
1650         E=1                                     ! |
1660         F=-1                                    ! |
1670      END IF                                     ! |
1680      FOR Gg=Dd TO E STEP F                      ! |
1690         IF C(Gg)<=Cfb THEN                      ! |
1700            GOTO 1750                            ! |
1710            ELSE                                 ! |
1720            GOTO 1740                            !  \
1730         END IF                                  !   \  Find flatband voltage on
1740      NEXT Gg                                    !   /  the first way.
1750      IF C(Gg)<>Cfb THEN                         !  /
1760         H=C(Gg-1)-C(Gg)                         ! |
1770         Ha=Cfb-C(Gg)                            ! |
1780         Hb=Ha/H                                 ! |
1790         Va=ABS(V(Gg-1)-V(Gg))                   ! |
1800         Vb=Va*Hb                                ! |
1810         IF V(Gg-1)>V(Gg) THEN                   ! |
1820            Vfb1=V(Gg)+Vb                        ! |
1830            ELSE                                 ! |
1840            Vfb1=V(Gg)-Vb                        ! |
1850         END IF                                  ! |
1860         ELSE                                    ! |
1870         Vfb1=V(Gg)                              ! /
1880      END IF                                     !/
1890      IF C(J)>C(I) THEN                          !\
1900         Dd=J                                    ! \
1910         E=I                                     ! |
1920         F=-1                                    ! |
1930         ELSE                                    ! |
1940         Dd=I                                    ! |
1950         E=J                                     ! |
1960         F=1                                     ! |
1970      END IF                                     ! |
1980      FOR Gg=Dd TO E STEP F                      ! |
1990         IF C(Gg)<=Cfb THEN                      ! |
2000            GOTO 2050                            ! |
2010            ELSE                                 ! |
```

```
2020          GOTO 2040                          !  \.
2030        END IF                               !   \  Find flatband voltage on
2040      NEXT Gg                                !   /  the back way.
2050      IF C(Gg)<>Cfb THEN                     !  /
2060        H=C(Gg+1)-C(Gg)                      ! |
2070        Ha=Cfb-C(Gg)                         ! |
2080        Hb=Ha/H                              ! |
2090        Va=ABS(V(Gg+1)-V(Gg))                ! |
2100        Vb=Va*Hb                             ! |
2110        IF V(Gg+1)>V(Gg) THEN                ! |
2120          Vfb2=V(Gg)+Vb                      ! |
2130          ELSE                               ! |
2140          Vfb2=V(Gg)-Vb                      ! |
2150        END IF                               ! |
2160        ELSE                                 ! |
2170        Vfb2=V(Gg)                           ! /
2180      END IF                                 !/
2190      Vfb=(Vfb1+Vfb2)/2
2200      PRINT TABXY(5,15);"Flatband voltage is ";TAB(49);Vfb;TAB(70);" V"
2210        !-----------------------------------------------------------!
2220        ! Find work function difference and interfacial state density. !
2230        !-----------------------------------------------------------!
2240      PRINT CHR$(131)
2250      PRINT TABXY(1,1);"Please select type of gate metal you used,Mg,Al,Ni,C
u,Ag,Au or the other metal"
2260      PRINT TABXY(1,2);"                                    (1-7).
                           "
2270      INPUT Mt
2280      IF Mt<=0 OR Mt>=8 THEN 2270
2290      ON Mt GOTO 2300,2320,2340,2360,2380,2400,2420
2300      Wfm=3.7                              ! Vacuum work function of Mg.
2310      GOTO 2440
2320      Wfm=4.2                              ! Vacuum work function of Al.
2330      GOTO 2440
2340      Wfm=4.74                             ! Vacuum work function of Ni.
2350      GOTO 2440
2360      Wfm=4.52                             ! Vacuum work function of Cu.
2370      GOTO 2440
2380      Wfm=4.31                             ! Vacuum work function of Ag.
2390      GOTO 2440
2400      Wfm=4.7                              ! Vacuum work function of Au.
2410      GOTO 2440
2420      PRINT TABXY(1,1);"Please input work function of gate metal."
2430      INPUT Wfm
2440      IF Wfm<=0 THEN 2430
2450      PRINT CHR$(128)
2460      PRINT TABXY(5,16);"Vacuum work function of gate metal is ";TAB(49);Wfm
;TAB(70);" V"
2470      IF St$="N" OR St$="n" THEN
2480        Wms=Wfm-(Eafs-Eg/2-Kb*T*LOG(Ncon/Ni))
2490        ELSE
2500        Wms=Wfm-(Eafs-Eg/2-Kb*T*LOG(Ni/Ncon))
2510      END IF
2520      PRINT TABXY(5,17);"Work function difference is ";TAB(49);Wms;TAB(70);"
 V"
```

```
2530      Ci=Cox/Ag
2540      Qss=(Wms-Vfb)*Ci/Q
2550      PRINT TABXY(5,18);"Interfacial state density is ";TAB(49);Qss;TAB(70);
" /cm2"
2560      PRINT CHR$(131)
2570      PRINT TABXY(1,1);"Would you like to print the result to the printer ?
((Y)es or (N)o)."
2580      INPUT P$
2590      IF P$<>"Y" AND P$<>"y" AND P$<>"N" AND P$<>"n" THEN 2580
2600      IF P$="Y" OR P$="y" THEN
2610         PRINT TABXY(1,1);"Printer is ready,press the CONTINUE key."
2620         PAUSE
2630         PRINT CHR$(128)
2640         PRINT TABXY(1,1);"                    THE IMPORTANT PARAMETER OF
MOS CAP.
2650         DUMP ALPHA #701
2660      END IF
2670   SUBEND
```

```
10          !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
20          !!                    MAIN PROGRAM                        !!
30          !! C-V CHARACTERISTICS (RECALL THA DATA FROM THE DISC)   !!
40          !!                       "DHA10"                          !!
50          !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
60     COM V(700),C(700),G(700),D(700)
70     COM REAL K1,K2,Y,C$[5],K$[5]
80     COM REAL Amax,Amin,Bmax,Bmin,Vcmax,Vcmin,Vgmax,Vgmin,INTEGER I,J,Op
90                          !-----------------------!
100    PRINT CHR$(12)
110    PRINT CHR$(129)
120    PRINT TABXY(10,10);" Please input the name of file which you want to reca
ll the data. "
130    INPUT F$
140    PRINT CHR$(12)
150    PRINT CHR$(129)
160    PRINT TABXY(10,10);" WOULD YOU LIKE TO RECALL YOUR DATA FROM MSI # ";CHR$
(131);"0";CHR$(129);" OR # ";CHR$(131);" 1";CHR$(129);" ?"
170    INPUT Msi
180    IF Msi=0 OR Msi=1 THEN 240
190       PRINT CHR$(128)
200       PRINT TABXY(10,12);" PLEASE PRESS ONLY '0' OR '1'. "
210       WAIT 3
220       PRINT TABXY(10,12);"                                        "
230       GOTO 170
240    IF Msi=0 THEN
250       MASS STORAGE IS ":,700,0"
260       ELSE
270       MASS STORAGE IS ":,700,1"
280    END IF
290    ASSIGN @File TO F$
300    ENTER @File,1;Amax
310    ENTER @File,2;Bmax
320    ENTER @File,3;Amin
330    ENTER @File,4;Bmin
340    ENTER @File,5;Vmax1
350    ENTER @File,6;Vmax2
360    ENTER @File,7;Vmin1
370    ENTER @File,8;Vmin2
380    ENTER @File,9;C$
390    ENTER @File,10;I
400    ENTER @File,11;J
410    FOR L=1 TO J
420       ENTER @File,L+11;V(L),C(L),G(L)
430    NEXT L
440    MASS STORAGE IS ":,700,1"
450    K1=V(1)
460    K2=V(I)
470    Vcmax=Vmax1
480    Vcmin=Vmin1
490    Vgmax=Vmax2
500    Vgmin=Vmin2
510    Po=POS(F$,"CG")
520    IF Po<>0 THEN
530       PRINT CHR$(12)
```

```
540       PRINT CHR$(129)
550       PRINT TABXY(10,10);" IF YOU WANT TO SEE C-V CURVE,PLEASE PRESS ";CHR$(
131);"'C'";CHR$(129);" KEY "
560       PRINT TABXY(10,11);"
 "
570       PRINT TABXY(10,12);" IF YOU WANT TO SEE G-V CURVE,PLEASE PRESS ";CHR$(
131);"ANY";CHR$(129);" KEY "
580       ELSE
590       PRINT CHR$(12)
600       PRINT CHR$(129)
610       PRINT TABXY(10,10);" IF YOU WANT TO SEE C-V CURVE,PLEASE PRESS ";CHR$(
131);"'C'";CHR$(129);" KEY "
620       PRINT TABXY(10,11);"
 "
630       PRINT TABXY(10,12);" IF YOU WANT TO SEE D-V CURVE,PLEASE PRESS ";CHR$(
131);"ANY";CHR$(129);" KEY "
640    END IF
650    INPUT K$
660    IF K$="C" THEN
670       LOADSUB Scaling FROM "DHA3"
680       LOADSUB Plot_linear FROM "DHA4"
690       PRINT CHR$(12)
700       Scaling
710       Plot_linear
720       PRINT CHR$(129)
730       PRINT TABXY(10,10);" Would you like to see another curve ? ((Y)es or(N
)o. "
740       INPUT P$
750       IF P$<>"Y" AND P$<>"y" AND P$<>"N" AND P$<>"n" THEN 740
760       IF P$="Y" OR P$="y" THEN
770          PRINT CHR$(129)
780          PRINT TABXY(10,12);" Would you like to see G-V curve in ";CHR$(131)
;"(S)";CHR$(129);"emilog or ";CHR$(131);"(L)";CHR$(129);"inear scale ? "
790          INPUT K$
800          IF K$<>"S" AND K$<>"s" AND K$<>"L" AND K$<>"l" THEN 790
810          IF K$="S" OR K$="s" THEN
820             LOADSUB Semilog FROM "DHA6"
830             LOADSUB Plot_semi FROM "DHA7"
840             PRINT CHR$(12)
850             Semilog
860             Plot_semi
870             PRINT TABXY(10,14);" Would you like to see G-V curve in linear s
cale ? (Y)es or (N)o. "
880             INPUT P$
890             IF P$<>"Y" AND P$<>"y" AND P$<>"N" AND P$<>"n" THEN 880
900             IF P$="Y" OR P$="y" THEN
910                LOADSUB Scaling_con FROM "DHA11"
920                LOADSUB Plot_linear_con FROM "DHA12"
930                PRINT CHR$(12)
940                Scaling_con
950                Plot_linear_con
960                ELSE
970                GOTO 880
980             END IF
990             ELSE
```

```
1000            LOADSUB Scaling_con FROM "DHA11"
1010            LOADSUB Plot_linear_con FROM "DHA12"
1020            PRINT CHR$(12)
1030            Scaling_con
1040            Plot_linear_con
1050            PRINT TABXY(10,14);" Would you like to see G-V curve in semilog
scale ? (Y)es or (N)o. "
1060            INPUT P$
1070            IF P$<>"Y" AND P$<>"y" AND P$<>"N" AND P$<>"n" THEN 1060
1080            IF P$="Y" OR P$="y" THEN
1090               LOADSUB Semilog FROM "DHA6"
1100               LOADSUB Plot_semi FROM "DHA7"
1110               PRINT CHR$(12)
1120               Semilog
1130               Plot_semi
1140               ELSE
1150               GOTO 1160
1160            END IF
1170         END IF
1180         ELSE
1190         GOTO 1200
1200      END IF
1210      ELSE
1220      PRINT CHR$(12)
1230      PRINT CHR$(129)
1240      PRINT TABXY(10,12);" Would you like to see G-V curve in ";CHR$(131);"(
S)";CHR$(129);"emilog or ";CHR$(131);"(L)";CHR$(129);"inear scale ? "
1250      INPUT K$
1260      IF K$<>"S" AND K$<>"s" AND K$<>"L" AND K$<>"l" THEN 1250
1270      IF K$="S" OR K$="s" THEN
1280         LOADSUB Semilog FROM "DHA6"
1290         LOADSUB Plot_semi FROM "DHA7"
1300         PRINT CHR$(12)
1310         Semilog
1320         Plot_semi
1330         PRINT TABXY(10,14);" Would you like to see G-V curve in linear scal
e ? (Y)es or (N)o. "
1340         INPUT P$
1350         IF P$<>"Y" AND P$<>"y" AND P$<>"N" AND P$<>"n" THEN 1340
1360         IF P$="Y" OR P$="y" THEN
1370            LOADSUB Scaling_con FROM "DHA11"
1380            LOADSUB Plot_linear_con FROM "DHA12"
1390            PRINT CHR$(12)
1400            Scaling_con
1410            Plot_linear_con
1420            ELSE
1430            GOTO 1440
1440         END IF
1450         ELSE
1460         LOADSUB Scaling_con FROM "DHA11"
1470         LOADSUB Plot_linear_con FROM "DHA12"
1480         PRINT CHR$(12)
1490         Scaling_con
1500         Plot_linear_con
1510         PRINT TABXY(10,14);" Would you like to see G-V curve in semilog sca
le ? (Y)es or (N)o. "
```

```
1520          INPUT P$
1530          IF P$<>"Y" AND P$<>"y" AND P$<>"N" AND P$<>"n" THEN 1520
1540          IF P$="Y" OR P$="y" THEN
1550             LOADSUB Semilog FROM "DHA6"
1560             LOADSUB Plot_semi FROM "DHA7"
1570             PRINT CHR$(12)
1580             Semilog
1590             Plot_semi
1600             ELSE
1610             GOTO 1620
1620          END IF
1630       END IF
1640       PRINT CHR$(12)
1650       PRINT CHR$(129)
1660       PRINT TABXY(10,10);"Would you like to see another curve ? ((Y)es or (N
)o. "
1670       INPUT P$
1680       IF P$<>"Y" AND P$<>"y" AND P$<>"N" AND P$<>"n" THEN 1670
1690       IF P$="Y" OR P$="y" THEN
1700          LOADSUB Scaling FROM "DHA3"
1710          LOADSUB Plot_linear FROM "DHA4"
1720          PRINT CHR$(12)
1730          Scaling
1740          Plot_linear
1750          ELSE
1760          GOTO 1770
1770       END IF
1780    END IF
1790    PRINT CHR$(12)
1800    PRINT CHR$(131)
1810    PRINT TABXY(1,18);" Would you like to analyse the impotant parameter of M
OS cap? ((Y)es or (N)o). "
1820    INPUT P$
1830    IF P$<>"Y" AND P$<>"y" AND P$<>"N" AND P$<>"n" THEN 1820
1840    IF P$="Y" OR P$="y" THEN
1850       LOADSUB Analyse_data FROM "DHAB"
1860       Analyse_data
1870       ELSE
1880       GOTO 1890
1890    END IF
1900    LOAD "MENU"
1910    END
```

```
10                      !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
20                      !! SCALING AND DRAW X-Y AXIS !!
30                      !!      IN LINEAR SCALE      !!
40                      !!    FOR THE CONDUCTANCE    !!
50                      !!         "DHA11"           !!
60                      !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
70    SUB Scaling_con
80    ! Wl,Wr,Wb,Wt       are the variables setting the reference of scailing.
90    ! Cal,Car,Cab,Cat   are the variables setting the boundary of axes.
100   ! Cfl,Cfr,Cfb,Cft   are the variables setting the boundary of graphics.
110   ! Xmax_gdu,Ymax_gdu are the parameter of screen
120   ! Xtick,Ytick,Xlocy |
130   ! Ylocx,Xmajor,Size > are the parameters of the 'AXES' statement.
140   ! Ymajor            |
150   ! M                 is the dummy variable.
160                           !--------------------!
170     COM V(*),C(*),G(*),D(*)
180     COM REAL K1,K2,Y,C$,K$
190     COM REAL Amax,Amin,Bmax,Bmin,Vcmax,Vcmin,Vgmax,Vgmin,INTEGER I,J,Op
200                           !--------------------!
210     Bmaxx=Bmax*10^7                    ! Maximum value of the MOS CON.
220     Bminx=Bmin*10^7                    ! Minimum value of the MOS CON.
230     Xmax_gdu=100*RATIO                 !\ Set parameter of screen.
240     Ymax_gdu=100                       !/
250     Ylocx=20*INT(Bminx/20)             ! Find pos. of X-axis on Y-axis.
260     Wl=MIN(K1,K2)-10                   !\
270     Wr=MAX(K1,K2)+10                   ! \ Set relative boundary.
280     Wb=Ylocx-40                        ! /
290     Wt=Bmaxx*1.2                       !/
300     Cal=Wl+5                           !\
310     Car=Wr-5                           ! \ Set parameter of soft clip.
320     Cab=Ylocx                          ! /
330     Cat=Bmaxx*1.1                      !/
340     Cfl=Cal-2                          !\
350     Cfr=Car+2                          ! \ Set parameter of frame.
360     Cfb=Ylocx-30                       ! /
370     Cft=Bmaxx*1.15                     !/
380     Xtick=1                            !\
390     Ytick=10                           ! \
400     Xlocy=0                            !  \ Set parameter of axis.
410     Xmajor=5                           !  /
420     Ymajor=5                           ! /
430     Size=3                             !/
440                         !------------------!
450     GINIT
460     DEG
470     GRAPHICS ON
480     LORG 5                                    !\
490     CSIZE 5                                   ! \
500     MOVE Xmax_gdu/2,.98*Ymax_gdu              ! !
510     LABEL "G-V CHARACTERISTICS"               ! !
520     CSIZE 4                                   ! !
530     MOVE Xmax_gdu/2,.93*Ymax_gdu              ! !
540     IF C$="F11" THEN LABEL "Measure at 100 Hz" ! !
550     IF C$="F12" THEN LABEL "Measure at 120 Hz" !  \
```

```
560       IF C$="F13" THEN LABEL "Measure at 200 Hz" !   > Label head of graph.
570       IF C$="F14" THEN LABEL "Measure at 400 Hz" !  /
580       IF C$="F15" THEN LABEL "Measure at 1 KHz"  ! |
590       IF C$="F16" THEN LABEL "Measure at 2 KHz"  ! |
600       IF C$="F17" THEN LABEL "Measure at 4 KHz"  ! |
610       IF C$="F18" THEN LABEL "Measure at 10 KHz" ! |
620       IF C$="F19" THEN LABEL "Measure at 20 KHz" ! |
630       IF C$="F20" THEN LABEL "Measure at 40 KHz" ! /
640       IF C$="F21" THEN LABEL "Measure at 100 KHz"!/
650       VIEWPORT .02*Xmax_gdu,.98*Xmax_gdu,.02*Ymax_gdu,.9*Ymax_gdu!\
660       WINDOW Wl,Wr,Wb,Wt                                          ! |
670       CLIP Cal,Car,Cab,Cat                                        !  \
680       AXES Xtick,Ytick,Xlocy,Ylocx,Xmajor,Ymajor,Size             !   > Line.
690       CLIP OFF                                                    !  /  scale
700       CLIP Cfl,Cfr,Cfb,Cft                                        ! |
710       FRAME                                                       !/
720                              !-----------------!
730       LORG 7                                    !\
740       FOR M=Ylocx TO Cat STEP 50                ! \
750          MOVE Xlocy,M                           !  \
760          CSIZE 4,.4                             !   \
770          LABEL M                                !    \ Label Y-axis.
780       NEXT M                                    !    /
790       MOVE 0,Cat                                !   /
800       IMOVE -3,0                                !  /
810       LDIR 90                                   ! /
820       LABEL "CONDUCTANCE*100 (nS)"              !/
830       LORG 6                                    !\
840       LDIR 360                                  ! \
850       FOR M=Cal TO Car STEP 1                   !  \
860          MOVE M,Ylocx                           !   \
870          IF M MOD 5=0 THEN LABEL M              !    > Label X-axis.
880       NEXT M                                    !   /
890       LORG 5                                    !  /
900       IMOVE -5,-10                              ! /
910       LABEL "VOLTAGE  (V)"                      !/
920    SUBEND
```

```
10                              !!!!!!!!!!!!!!!!!!!!!!!!!!
20                              !!     PLOT PROGRAM     !!
30                              !!   IN LINEAR SCALE    !!
40                              !! FOR THE CONDUCTANCE  !!
50                              !!      "DHA12"         !!
60                              !!!!!!!!!!!!!!!!!!!!!!!!!!
70      SUB Plot_linear_con
80      ! O     is the pointer variable.
90      ! P$    is the variable to keep the answer string.
100                             !---------------!
110        COM V(*),C(*),G(*),D(*)
120        COM REAL K1,K2,Y,C$,K$
130        COM REAL Amax,Amin,Bmax,Bmin,Vcmax,Vcmin,Vgmax,Vgmin,INTEGER I,J,Op
140        DIM Gx(700)
150                            !---------------!
160        GRAPHICS ON
170        Gx(1)=G(1)*10^7                  !\
180        MOVE V(1),Gx(1)                  ! \
190        DRAW V(1),Gx(1)                  !  \
200        FOR O=2 TO I                     !   > Plot cuvre with increasing volt.
210           Gx(O)=G(O)*10^7               !  /
220           DRAW V(O),Gx(O)               ! /
230        NEXT O                           !/
240        FOR O=I+1 TO J                   !\
250           Gx(O)=G(O)*10^7               ! \ Plot cuvre with decreasing voltage.
260           DRAW V(O),Gx(O)               ! /
270        NEXT O                           !/
280                                !------------------!
290        PRINT CHR$(12)
300        PRINT CHR$(129)
310        PRINT TABXY(10,10);" Would you like to have a paper of your G/V curve
? (y or n) "
320        INPUT P$
330        IF P$<>"Y" AND P$<>"y" AND P$<>"N" AND P$<>"n" THEN 320
340        IF P$="N" OR P$="n" THEN 480
350        PRINT TABXY(10,10);" If you would like to print the curve by printer,p
lease press key 'A'. "
360        PRINT TABXY(10,11);" If you would like to plot the curve by plotter,pl
ease press any key.  "
370        INPUT Pr$
380        IF Pr$="A" THEN
390           PRINT CHR$(131)
400           PRINT TABXY(25,16);" PRINTER IS READY,PRESS CONTINUE KEY "
410           PAUSE
420           PRINT CHR$(12)
430           DUMP GRAPHICS #701
440           ELSE
450           LOADSUB Plotter FROM "DHA10"
460           Plotter
470           PRINT CHR$(12)
480        END IF
490     GRAPHICS OFF
500     SUBEND
```

```
10                      !!!!!!!!!!!!!!!!!!!!!!!!!!!!
20                      !! DATA RECORDING PROGRAM !!
30                      !!        "DHA14"         !!
40                      !!!!!!!!!!!!!!!!!!!!!!!!!!!!
50      SUB Record
60      ! I,J         are the counters of set of input data.
70      ! A,B,Amax,Amin,Bmax,Bmin are the dummy variables.
80      ! Vcmax,Vcmin are the values of voltage which capacitance is  -
90      !             maximum and minimum,respectively.
100     ! Vgmax,Vgmin are the values of voltage which conductance is  -
110     !             maximum and minimum,respectively.
120     ! Vdmax,Vdmin are the values of voltage which dispation factor-
130     !             is maximum and minimum,respectively.
140     ! F$          keeps the name of data file which is created.
150     ! L           is the variable to point each set of data keeped in files.
160     ! Msi         is the variable to keep the number of mass storage.
170                         !-------------------!
180        COM V(*),C(*),G(*),D(*)
190        COM REAL K1,K2,Y,C$,K$
200        COM REAL Amax,Amin,Bmax,Bmin,Vcmax,Vcmin,Vgmax,Vgmin,INTEGER I,J,Op
210                      !------------------!
220        PRINT CHR$(12)
230        PRINT CHR$(129)
240        PRINT TABXY(1,10);" PLEASE INPUT THE NAME OF DATA FILE,SHOULD GIVE IN
FORM 'CB1,CD2,etc.' DEPEND "
250        PRINT TABXY(1,11);"                                    ON TYPE OF DATA.
                             "
260        LINPUT F$
270        PRINT CHR$(12)
280        PRINT CHR$(129)
290        PRINT TABXY(10,10);" WOULD YOU LIKE TO RECORD YOUR DATA IN MSI #";CHR$
(131);" 0";CHR$(129);" OR #";CHR$(131);" 1";CHR$(129);" ?"
300        INPUT Msi
310        IF Msi=0 OR Msi=1 THEN 370
320           PRINT CHR$(128)
330           PRINT TABXY(10,12);" PLEASE PRESS ONLY '1' OR '0' "
340           WAIT 3
350           PRINT TABXY(10,12);"                              "
360           GOTO 300
370        IF Msi=0 THEN
380           MASS STORAGE IS ":,700,0"
390           ELSE
400           MASS STORAGE IS ":,700,1"
410        END IF
420        PRINT CHR$(131)
430        PRINT TABXY(10,17);" PLEASE WAIT A MOMENT,PROGRAM IS RECORDING YOUR DA
TA. "
440        CREATE BDAT F$,J+11,24
450        ASSIGN @File TO F$
460        OUTPUT @File,1;Amax
470        OUTPUT @File,2;Bmax
480        OUTPUT @File,3;Amin
490        OUTPUT @File,4;Bmin
500        OUTPUT @File,5;Vcmax
510        OUTPUT @File,6;Vgmax
```

```
520       OUTPUT @File,7;Vcmin
530       OUTPUT @File,8;Vgmin
540       OUTPUT @File,9;C$
550       OUTPUT @File,10;I
560       OUTPUT @File,11;J
570       FOR L=1 TO J
580          IF K$="A" THEN
590             OUTPUT @File,L+11;V(L),C(L),G(L)
600             ELSE
610             OUTPUT @File,L+11;V(L),C(L),D(L)
620          END IF
630       NEXT L
640       PRINT CHR$(128)
650       PRINT TABXY(10,17);"
          "
660       MASS STORAGE IS ":,700,1"
670       BEEP
680    SUBEND
```

```
10                    !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
20                    !! RESISTANCE MEASUREMENT PROGRAM !!
30                    !!            "RESIST"              !!
40                    !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
50     PRINT CHR$(12)
60     PRINT CHR$(128)
70     PRINT TABXY(15,1);"**********************************************************"
80     PRINT TABXY(15,2);"**           Resistance measurement program.          **"
90     PRINT TABXY(15,3);"**********************************************************"
100    PRINT TABXY(15,5);"This program is used for measuring the diffused resist
or by"
110    PRINT TABXY(10,6);"4140B pA meter/DC voltage source. The resistance of th
e resistor"
120    PRINT TABXY(10,7);"which you would like to measure should not be too smal
l,10 ohms."
130    PRINT TABXY(10,8);"Because you may get the error from the measurement."
140    PRINT TABXY(15,9);"Before you will measure the resistor by this program,p
lease"
150    PRINT TABXY(10,10);"warm up the 4140B for an hour and connect the I-INPUT
 and Va-OUT"
160    PRINT TABXY(10,11);"PUT PROBE of the 4140B with the connector of the prob
e station."
170    PRINT CHR$(131)
180    PRINT TABXY(15,18);" WHEN YOU ARE READY,PLEASE PRESS THE 'CONTINUE' KEY.
"
190    PAUSE
200                        !-----------------------!
210    DIM I(500),R(500)
220    PRINT CHR$(12)
230    PRINT CHR$(129)
240    PRINT TABXY(15,10);" HOW MANY RESISTORS WOULD YOU LIKE TO MEASURE NOW ? "
250    INPUT X
260    IF X=0 THEN 520
270    V=.1
280    V$=VAL$(V)
290    REDIM I(X),R(X)
300                        !-----------------------!
310    OUTPUT 716;"R12"
320    WAIT 1
330    OUTPUT 716;"Z"
340    OUTPUT 716;"W7"
350    OUTPUT 716;"F1"
360    OUTPUT 716;"RA1"
370    OUTPUT 716;"H12"
380    OUTPUT 716;"J1"
390    OUTPUT 716;"W2"
400    OUTPUT 716;"A5"
410    OUTPUT 716;"B2"
420    OUTPUT 716;"L3"
430    OUTPUT 716;"PA";V$
440                        !-----------------------!
450    FOR J=1 TO X
460       PRINT CHR$(129)
470       PRINT TABXY(10,10);" PLEASE CONNECT YOUR RESISTOR WITH THE CONNECTOR O
F pA METER. "
```

```
480       PRINT CHR$(131)
490       PRINT TABXY(10,12);" WHEN YOU ARE READY,PLEASE PRESS THE 'CONTINUE' KE
Y. "
500       PAUSE
510       OUTPUT 716;"W1"
520       ENTER 716;A
530       I(J)=A
540       R(J)=V/I(J)
550       PRINT CHR$(128)
560       PRINT TABXY(30,15);"                                        "
570       PRINT TABXY(30,15);"R";J;" = ";R(J)
580    NEXT J
590    PRINT CHR$(129)
600    PRINT TABXY(5,18);" IF YOU WANT TO DO THE NEXT STATE,PLEASE PRESS THE 'CO
NTINUE' KEY. "
610    PAUSE
620    PRINT CHR$(12)
630    PRINT CHR$(129)
640    PRINT TABXY(2,10);" PLEASE INPUT THE NAME OF DATA FILE TO KEEP THE RESIST
ANCE VALUES,SHOULD GIVE "
650    PRINT TABXY(2,11);"                              IN FORM 'RE1,RE2,etc.'.
                         "
660    INPUT F$
670    PRINT CHR$(12)
680    PRINT CHR$(128)
690    PRINT TABXY(10,10);"Would you like to store your data in MSI # ";CHR$(130
);"0";CHR$(128);" or # ";CHR$(130);"1";CHR$(128);" ?"
700    INPUT P
710    IF P<>0 AND P<>1 THEN 700
720    IF P=0 THEN
730       MASS STORAGE IS ":,700,0"
740       ELSE
750       MASS STORAGE IS ":,700,1"
760    END IF
770    PRINT CHR$(131)
780    PRINT TABXY(10,15);" PLEASE WAIT A MOMENT,PROGRAM IS RECORDING YOUR DATA.
 "
790    CREATE BDAT F$,X+1,8
800    ASSIGN @File TO F$
810    OUTPUT @File,1;X
820    FOR K=1 TO X
830       OUTPUT @File,K+1;R(K)
840    NEXT K
850    MASS STORAGE IS ":,700,1"
860    PRINT CHR$(12)
870    PRINT CHR$(129)
880    PRINT TABXY(10,10);" Now,you have already had the resistance data in your
 disk. "
890    BEEP
900    LOAD "MENU"
910    END
```

```
10                    !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
20                    !! READING RESISTANCE DATA PROGRAM !!
30                    !!          "RESIST_OUT"           !!
40                    !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
50      DIM R(500)
60      PRINT CHR$(12)
70      PRINT CHR$(129)
80      PRINT TABXY(4,10);" Please input your resistance data file whitch you wan
t to see the data. "
90      INPUT F$
100     PRINT CHR$(12)
110     PRINT CHR$(129)
120     PRINT TABXY(10,10);" WOULD YOU LIKE TO RECALL YOUR DATA IN MSI # ";CHR$(1
31);"0";CHR$(129);" OR # ";CHR$(131);"1";CHR$(129);" ?"
130     INPUT P
140     IF P<>0 AND P<>1 THEN 130
150     IF P=0 THEN
160        MASS STORAGE IS ":,700,0"
170        ELSE
180        MASS STORAGE IS ":,700,1"
190     END IF
200     ASSIGN @File TO F$
210     ENTER @File,1;X
220     FOR J=1 TO X
230        ENTER @File,J+1;R(J)
240     NEXT J
250     MASS STORAGE IS ":,700,1"
260     PRINT CHR$(12)
270     PRINT CHR$(128)
280     FOR K=1 TO X/2
290        PRINTER IS 701
300        PRINT "R";K;" = ";R(K),"R";K+X/2;" = ";R(K+X/2)
310     NEXT K
320     PRINTER IS 1
330     LOAD "MENU"
340     END
```

```
10                      !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
20                      !! FINDING THRESHOLD VOLTAGE PROGRAM !!
30                      !!              "MOS_T1"             !!
40                      !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
50      ! V1,V1$  is the variable keeping the starting voltage.
60      ! V2,V2$  is the variable keeping the stopping voltage.
70      ! Dv,Dv$  is the variable keeping the stepping voltage.
80      ! V10     is the variable keeping the voltage value at the drain current
90      !         10 uA.
100     ! V40     is the variable keeping the voltage value at the drain current
110     !         40 uA.
120     ! Vt      is the threshold voltage.
130        PRINT CHR$(12)
140        PRINT CHR$(128)
150        PRINT TABXY(10,10);" Please input the voltage range which you want to
find the threshold"
160        PRINT TABXY(10,11);" voltage of MOSFET. "
170        PRINT CHR$(129)
180        PRINT TABXY(10,13);" WHAT IS THE STARTING VOLTAGE ? "
190        INPUT V1
200        IF V1<-100 OR V1>100 THEN
210           PRINT CHR$(131)
220           PRINT TABXY(10,15);" YOUR STARTING VOLTAGE IS OVER RANGE,PLEASE GIV
E THE NEW VALUE. "
230           GOTO 190
240        END IF
250        PRINT CHR$(128)
260        PRINT TABXY(10,15);"
              "
270        PRINT CHR$(129)
280        PRINT TABXY(10,13);" WHAT IS THE STOPPING VOLTAGE ? "
290        INPUT V2
300        IF V2<-100 OR V2>100 THEN
310           PRINT CHR$(131)
320           PRINT TABXY(10,15);" YOUR STOPPING VOLTAGE IS OVER RANGE,PLEASE GIV
E THE NEW VALUE. "
330           GOTO 290
340        END IF
350        PRINT CHR$(128)
360        PRINT TABXY(10,15);"
              "
370        PRINT CHR$(129)
380        PRINT TABXY(10,13);" WHAT IS THE STEP VOLTAGE OF STAIRCASE ? "
390        INPUT Dv
400        IF Dv<-10 OR Dv>10 THEN
410           PRINT CHR$(131)
420           PRINT TABXY(10,15);" YOUR STEP VOLTAGE IS OVER RANGE,PLEASE GIVE TH
E NEW VALUE. "
430           GOTO 390
440        END IF
450        PRINT CHR$(129)
460        PRINT TABXY(10,13);" WHAT IS THE CONSTANT VOLTAGE FOR THE DRAIN TERMIN
AL ? "
470        INPUT Vb
480        IF Vb<-100 OR Vb>100 THEN
```

```
490         PRINT CHR$(131)
500         PRINT TABXY(10,15);" YOUR DRAIN VOLTAGE IS OVER RANGE,PLEASE GIVE T
HE NEW VALUE. "
510         GOTO 470
520       END IF
530       PRINT CHR$(128)
540       PRINT TABXY(10,15);"
            "
550       PRINT TABXY(10,13);"
    "
560       PRINT CHR$(12)
570       PRINT CHR$(128)
580       PRINT TABXY(10,10);" The voltage range whitch you want to find the thr
eshold voltage"
590       PRINT TABXY(10,11);" is"
600       PRINT TABXY(25,13);" THE STARTING VOLTAGE IS ";V1;" V."
610       PRINT TABXY(25,14);" THE STOPPING VOLTAGE IS ";V2;" V."
620       PRINT TABXY(25,15);" THE STEP VOLTAGE IS     ";Dv;" V."
630       PRINT TABXY(25,16);" THE DRAIN VOLTAGE IS    ";Vb;" V."
640       Y=(V2-V1)/Dv
650       V1$=VAL$(V1)
660       V2$=VAL$(V2)
670       Dv$=VAL$(Dv)
680       Vb$=VAL$(Vb)
690       PRINT CHR$(129)
700       PRINT TABXY(15,18);" When you are ready,please press the 'CONTINUE' ke
y. "
710       PAUSE
720                              !--------------------!
730       OUTPUT 716;"R12"
740       OUTPUT 716;"I"
750       OUTPUT 716;"W7"
760       OUTPUT 716;"F1"
770       OUTPUT 716;"RA1"
780       OUTPUT 716;"H12"
790       OUTPUT 716;"12"
800       OUTPUT 716;"J1"
810       OUTPUT 716;"A3"
820       OUTPUT 716;"B1"
830       OUTPUT 716;"L3"
840       OUTPUT 716;"M3"
850       OUTPUT 716;"PB";Vb$
860       OUTPUT 716;"PS";V1$
870       OUTPUT 716;"PT";V2$
880       OUTPUT 716;"PE";Dv$
890       OUTPUT 716;"PH0.5"
900       OUTPUT 716;"W2"
910       OUTPUT 716;"W1"
920                              !--------------------!
930       PRINT CHR$(12)
940       PRINT CHR$(128)
950       PRINT TABXY(15,5);"Please connect your sample following this connectio
n."
960       PRINT TABXY(10,7);"1. Gate is connected to VA terminal of pA meter."
970       PRINT TABXY(10,8);"2. Drain is connected to VB terminal of pA meter."
```

```
980       PRINT TABXY(10,9);"3. Source and the substrate are connected to the HI
GH terminal of pA -"
990       PRINT TABXY(10,10);"   meter."
1000      PRINT TABXY(10,11);"4. The LOW terminal of pA meter is connected to th
e GROUD of system."
1010      PRINT CHR$(129)
1020      PRINT TABXY(10,18);" WHEN YOU ARE READY,PLEASE PRESS THE 'CONTINUE' KE
Y "
1030      PAUSE
1040                          !--------------------!
1050      PRINT CHR$(12)
1060      PRINT CHR$(131)
1070      PRINT TABXY(15,10);" Please wait a moment,program is running. "
1080      FOR X=1 TO Y
1090         ENTER 716;A
1100         IF ABS((1.0E-4)-A)<=5.0E-6 THEN
1110            V100=V1+(Dv*X)
1120         END IF
1130         IF ABS((4.0E-4)-A)<=5.0E-6 THEN
1140            V400=V1+(Dv*X)
1150         END IF
1160         OUTPUT 716;"W6"
1170      NEXT X
1180      Vt=2*V100-V400
1190      PRINT CHR$(128)
1200      PRINT TABXY(10,10);"                                                  "
1210                          !--------------------!
1220      PRINT CHR$(12)
1230      PRINT CHR$(129)
1240      PRINT TABXY(15,10);" THRESHOLD VOLTAGE OF MOSFET IS ";Vt;" V "
1250      PRINT CHR$(128)
1260      PRINT TABXY(15,12);" V100 = ";V100;" V.,V400 = ";V400;" V.,Vd = ";Vb;"
V."
1270      BEEP
1280      PRINT CHR$(129)
1290      PRINT TABXY(10,18);" When you are ready,please press the CONTINUE key.
"
1300      PAUSE
1310      OUTPUT 716;"W7"
1320      LOAD "MENU"
1330      END
```

ภาคผนวก ข.
เงื่อนไขของขั้นตอนการผลิตสิ่งประดิษฐ์มอส

การทำ Final cleaning

1. ล้างแว่นผลึกใน Trichloroethylene ด้วย Ultrasonic cleaner (ร้อน) นาน 10 นาที
2. ล้างแว่นผลึกใน Acetone ด้วย Ultrasonic cleaner (ร้อน) นาน 10 นาที
3. ล้างแว่นผลึกใน DI water ด้วย Ultrasonic cleaner (ร้อน) นาน 10 นาที
4. เปลี่ยน DI water ใหม่และล้างแว่นผลึกใน DI water ด้วย Ultrasonic cleaner (ร้อน) อีก 10 นาที
5. เป่าแห้งด้วยก๊าซ N_2
6. นำแว่นผลึกจุ่มลงใน HNO_3 (70%) เดือดนาน 10 นาที
7. ล้างแว่นผลึกด้วย DI water และเป่าแห้งด้วยก๊าซ N_2
8. นำแว่นผลึกจุ่มลงใน Buffer HF 1 นาที
9. ล้างแว่นผลึกด้วย DI water และเป่าแห้งด้วยก๊าซ N_2

การทำ Photolithography โดยใช้ Positive photoresist

เป็นกระบวนการถ่ายแบบจากหน้ากากที่ได้ออกแบบไว้ (ฟิล์มกระจก) ลงบนแว่นผลึก โดยใช้ photoresist ชนิด positive ของ Shipley รุ่น AZ1350

ขั้นตอนในการทำ Photolithography มีดังนี้คือ

1. อบแว่นผลึกในเตาอุณหภูมิ 120 °C นาน 30 นาที
2. เคลือบ Photoresist ลงบนแว่นผลึกด้วย Spinner ที่ความเร็ว 5000 รอบ/นาที นาน 20 วินาที
3. อบแห้งแว่นผลึกในเตาอุณหภูมิ 80 °C เป็นเวลา 30 นาที

4. นำแว่นผลึกมาถ่ายแบบโดยฉายแสงอุลตราไวโอเลตนาน 20 วินาที
5. Develope ด้วยน้ำยาเคมีนาน 1 นาที
6. ล้างแว่นผลึกด้วย DI water และเป่าแห้งด้วยก๊าซ N_2
7. อบแห้งแว่นผลึกในเตาอุณหภูมิ 120 °C นาน 15 นาที

<u>การทำ Photolithography โดยใช้ Negative photoresist</u>

เป็นกระบวนการถ่ายแบบจากหน้ากากที่ได้ออกแบบไว้ โดยใช้ Photoresist ชนิด negative รุ่น OMR-83

ขั้นตอนในการทำ Photolithography มีดังนี้คือ

1. ล้างแว่นผลึกด้วย Trichloroethylene, Acetone และน้ำ DI
2. เป่าแห้งด้วยก๊าซ N_2
3. อบแว่นผลึกในเตาอุณหภูมิ 120 °C นาน 30 นาที
4. เคลือบ Photoresist ลงบนแว่นผลึกด้วย Spinner ที่ความเร็ว 4000 รอบ/นาที นาน 20 วินาที
5. อบแห้งแว่นผลึกในเตาอุณหภูมิ 70 °C นาน 20 นาที
6. นำแว่นผลึกมาถ่ายแบบโดยฉายแสงอุลตราไวโอเลตนาน 20 วินาที
7. Develope ด้วยน้ำยา OMR-SL เป็นเวลา 3 นาที
8. ล้างน้ำยา Developer OMR-SL ออกจากแว่นผลึกด้วยน้ำยา OMR-Buthyl acetate
9. เป่าแห้งด้วยก๊าซ N_2
10. อบแห้งแว่นผลึกในเตาอุณหภูมิ 120 °C นาน 25 นาที

การล้าง Photoresist OMR-83 ออกจากแว่นผลึกหลังจากการกัดอลูมิเนียมเรียบร้อยแล้ว ทำโดยการจุ่มแว่นผลึกลงใน Stripper OMR-502 เดือดนาน 2 นาที

ภาคผนวก ค.
การคำนวณลักษณะสมบัติของสิ่งประดิษฐ์มอสทางทฤษฎี

MOS Capacitor Characteristics (4)

q : = $1.602*10^{-19}$ [Electron Charge (Coulomb)]

Qss : = $6.2*10^{11}*q$ [Interface state density (Coulomb/cm(2))]

Na : = $1.0*10^{15}$ [Substrate concentration (cm(-3))]

ni : = $1.5*10^{10}$ [Intrinsic concentration (cm(-3))]

k : = $1.38*10^{-23}$ [Boltzmann constant (J/K)]

ε_s : = $1.04*10^{-12}$ [Si permittivity (F/cm)]

ε_{ox} : = $3.45*10^{-13}$ [SiO_2 permittivity (F/cm)]

A : = .0025 [Gate area (cm(2))]

d : = $1.0*10^{-5}$ [Gate oxide thickness (cm)]

Cox : = $\frac{\varepsilon_{ox}*A}{d} * 10^{12}$ [Oxide capacitance (pF)]

$C_{ox} = 86.25$

Coxa : = $\frac{Cox}{A} * 10^{-12}$ [Oxide capacitance per unit area (F/cm(2))]

$$Coxa = 3.45*10^{-8}$$

$$Vox := \frac{Qss}{Coxa} \qquad Vox = 2.879 \quad \text{(Volts)}$$

$$T := 300 \quad \text{(Kelvin)}$$

$$Vq := -20.5 \quad \text{(Volts)}$$

$$X := 0 .. 50$$

$$V1_X := Vq + X \quad \text{[Surface potential (Volts)]}$$

$$V_X := V1_X + Vox \quad \text{[Gate voltoge (volts)]}$$

$$Ub := \ln\left[\frac{Na}{ni}\right] \quad \text{(Volts)}$$

$$Cfbs := A\sqrt{\frac{\varepsilon_s * q^2 * Na}{k*T}} * 10^{12} \quad \text{[Surface flatband capacitance (pF)]}$$

$$Cfbs = 200.733$$

$$Cfb := \frac{Cfbs*Cox}{Cfbs + Cox} \quad \text{[Flatband capacitance (pF)]}$$

$$Cfb = 60.328$$

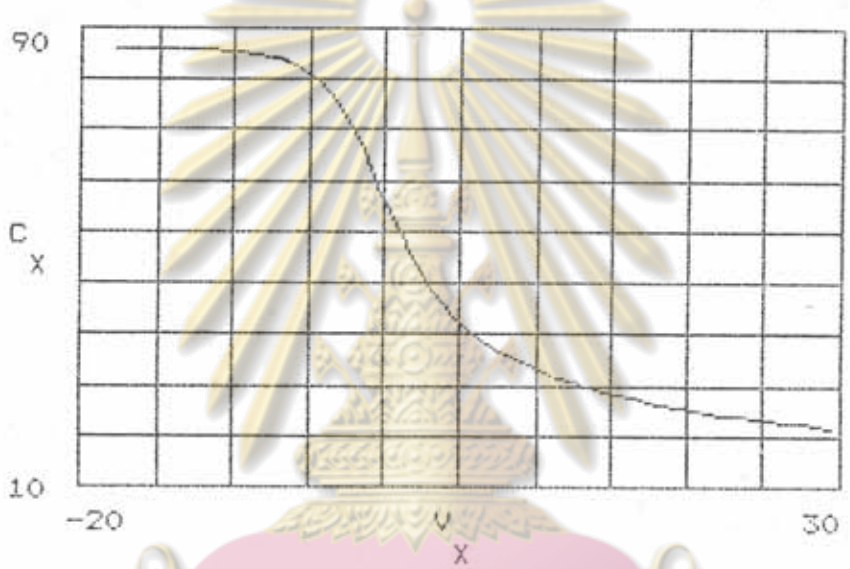
$$F_X := 2 * V_X + \exp[-V_X] - 1$$

$$Delta_X := \left[\frac{F_X}{\exp[V_X]-1}\right] \int_0^{V_X} \left[\frac{\exp(Vs)-\exp(-Vs)-2*Vs}{[\,2 * Vs+\exp(-Vs)-1+\exp(2*Ub)*[\exp[V_X]-1]\,]^3}\right] dVs - 1]$$

$$Y_X := \text{if } [V_X > 0,1,-1] \quad [\text{Sqn. Fn}]$$

$$Cs_X := Y_X * Cfbs * \frac{1-\exp[-V_X]+[\frac{ni}{Na}]^2 * [[\exp[V_X]-1]*[\frac{Delta_X}{1+Delta_X}]+1]}{F_X}$$

$$C_X := \frac{Cs_X * Cox}{Cs_X + Cox} \qquad [\text{MOS capacitance (pF)}]$$



CHARACTERISTICS of MOSFET : W=700. um,L=50 um (33)

$Q := 1.6 \cdot 10^{-19}$ [Electron charge (Coulomb)]

$\mu := 1360$ [Electron mobility (cm2/volt*sec)]

$\epsilon s := 1.04 \cdot 10^{-12}$ [Si permittivity]

$Eafs := 4.23$ [Electron affinity (Volts)]

$Wfm := 4.2$ [Work function of Al (Volts)]

$Eq := 1.12$ [Band gap energy of Si]

$Kb := 1.38 \cdot 10^{-23}$ [Boltzman constant (J/K)]

$T := 300$ [Room temparature (Kelvin)]

$Na := 1.0 \cdot 10^{15}$ [Substrate concentration (cm(-3))]

$ni := 1.5 \cdot 10^{10}$ [Intrinsic concentration (cm(-3))]

$$Wms := Wfm - \left[Eafs - \frac{Eq}{2} - Kb \cdot T \cdot \ln\left[\frac{ni}{Na}\right] \right] \qquad Wms = 0.53$$

[Wms - Work function difference (Volts)]

$$\phi b := \frac{Kb \cdot T \cdot \ln\left[\frac{Na}{ni}\right]}{Q} \qquad \phi b = 0.287 \quad \text{[Volts]}$$

$Qss := 6.3 \cdot 10^{11}$ [Interface state density (cm(-2))]

$A := .0025$ [Gate area (cm2)]

$Cox := 86.25 \cdot 10^{-12}$ [Oxide capacitance (Farad)]

$$Coxa := \frac{Cox}{A}$$ [Farad/cm2]

[Coxa - Oxide capacitance per unit area]

$$Vfb := Wms - \frac{Qss \cdot Q}{Coxa} \qquad Vfb = -2.392 \quad [Volts]$$

[Vfb - Flat-band voltage]

$$\Gamma := \frac{\sqrt{2 \cdot \epsilon s \cdot Q \cdot Na}}{Cox} \cdot A \qquad \Gamma = 0.529$$

[Γ - Body-effect parameter]

$$Vth := Vfb + 2 \cdot \phi b + \Gamma \cdot \sqrt{2 \cdot \phi b}$$

Vth = -1.416 [Volts]

[Vth - Threshold voltage]

Wq := 700 [Width of gate (um)]

Leff := 50 [Lenght of gate (um)]

$$\beta := \frac{\mu \cdot Coxa \cdot Wq}{Leff} \qquad \beta = 6.569 \cdot 10^{-4}$$

$$Idss := \frac{\beta}{2} \cdot (0 - Vth)^2 \qquad Idss = 6.586 \cdot 10^{-4}$$

[Idss - Drain current at zero gate bias (Amp)]

Vga := -0.182

[Vga - Gate voltage at Ids=500 uA (Volts)]

$$Gm := \beta \cdot (Vga - Vth) \qquad Gm = 8.106 \cdot 10^{-4}$$

[Gm - Transconductance (mhos)]

Vgs := 1.0 [Starting gate voltage (Volts)]

X := 0 ..10

$Vg_X := Vgs + (X \cdot 1.0)$ [Gate voltage (Volts)]

Vds := 0 [Starting drain-source voltage (Volts)]

Y := 0 ..100

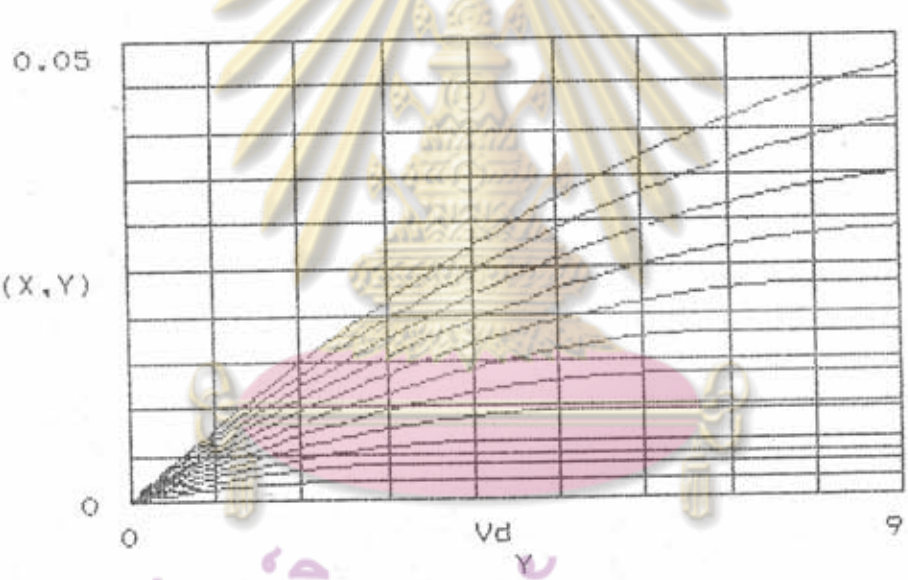
$Vd_Y := Vds + (Y \cdot 0.1)$ [Drain-source voltage (Volts)]

$$I(X,Y) := \beta \cdot \left[\left[Vg_X - Vth \right] \cdot Vd_Y - \frac{Vd_Y^2}{2} \right]$$

$$I1(X,Y) := \frac{\beta}{2} \left[Vg_X - Vth \right]^2$$

$$Vdssat_X := Vg_X - Vth$$

$$I2(X,Y) := if\left[Vd_Y \geq Vdssat_X, I1(X,Y), I(X,Y) \right]$$



I(X,Y) - Drain current (linear region)

I1(X,Y) - Drain current (saturation region)

I2(X,Y) - Drain current

CHARACTERISTICS of MOSFET : W=700 um,L=75 um (33)

$q := 1.6 \cdot 10^{-19}$ [Electron charge (Coulomb)]

$\mu := 1360$ [Electron mobility (cm2/volt*sec)]

$\epsilon s := 1.04 \cdot 10^{-12}$ [Si permittivity]

$Eafs := 4.23$ [Electron affinity (Volts)]

$Wfm := 4.2$ [Work function of Al (Volts)]

$Eq := 1.12$ [Band gap energy of Si]

$Kb := 1.38 \cdot 10^{-23}$ [Boltzman constant (J/K)]

$T := 300$ [Room temparature (Kelvin)]

$Na := 1.0 \cdot 10^{15}$ [Substrate concentration (cm(-3))]

$ni := 1.5 \cdot 10^{10}$ [Intrinsic concentration (cm(-3))]

$$Wms := Wfm - \left[Eafs - \frac{Eq}{2} - Kb \cdot T \cdot \ln\left[\frac{ni}{Na}\right] \right] \qquad Wms = 0.53$$

[Wms - Work function difference (Volts)]

$$\phi b := \frac{Kb \cdot T \cdot \ln\left[\frac{Na}{ni}\right]}{q} \qquad \phi b = 0.287 \quad \text{[Volts]}$$

$Qss := 6.3 \cdot 10^{11}$ [Interface state density (cm(-2))]

$A := .0025$ [Gate area (cm2)]

$Cox := 86.25 \cdot 10^{-12}$ [Oxide capacitance (Farad)]

$$Coxa := \frac{Cox}{A}$$ [Farad/cm2]

[Coxa - Oxide capacitance per unit area]

$$Vfb := Wms - \frac{Qss \cdot Q}{Coxa} \qquad Vfb = -2.392 \quad [Volts]$$

[Vfb - Flat-band voltage]

$$\Gamma := \frac{\sqrt{2 \cdot \epsilon s \cdot Q \cdot Na}}{Cox} \cdot A \qquad \Gamma = 0.529$$

[Γ - Body-effect parameter]

$$Vth := Vfb + 2 \cdot \phi b + \Gamma \cdot \sqrt{2 \cdot \phi b}$$

Vth = -1.416 [Volts]

[Vth - Threshold voltage]

Wq := 700 [Width of gate (um)]

Leff := 75 [Lenght of gate (um)]

$$\beta := \frac{\mu \cdot Coxa \cdot Wq}{Leff} \qquad \beta = 4.379 \cdot 10^{-4}$$

$$Idss := \frac{\beta}{2} \cdot (0 - Vth)^2 \qquad Idss = 4.39 \cdot 10^{-4}$$

[Idss - Drain current at zero gate bias (Amp)]

Vga := 0.095

[Vga - Gate voltage at Ids=500 uA (Volts)]

$$Gm := \beta \cdot (Vga - Vth) \qquad Gm = 6.617 \cdot 10^{-4}$$

[Gm - Transconductance (mhos)]

Vgs := 1.0 [Starting gate voltage (Volts)]

X := 0 ..10

$Vg_X := Vgs + (X \cdot 1.0)$ [Gate voltage (Volts)]

Vds := 0 [Starting drain-source voltage (Volts)]

Y := 0 ..100

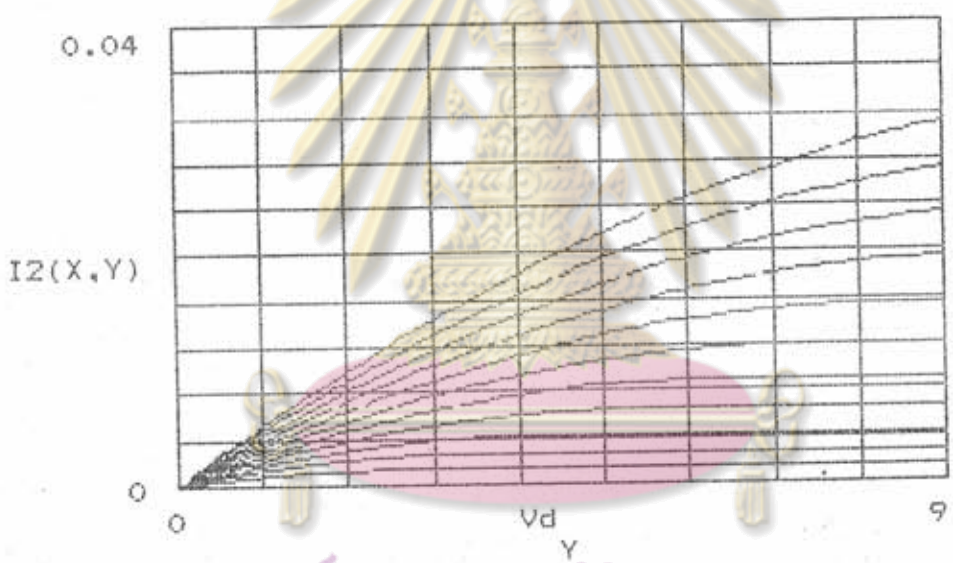
$Vd_Y := Vds + (Y \cdot 0.1)$ [Drain-source voltage (Volts)]

$$I(X,Y) := \beta \cdot \left[\left[Vg_X - Vth \right] \cdot Vd_Y - \frac{Vd_Y^2}{2} \right]$$

$$I1(X,Y) := \frac{\beta}{2} \left[Vg_X - Vth \right]^2$$

$Vdssat_X := Vg_X - Vth$

$I2(X,Y) := if\left[Vd_Y \geq Vdssat_X, I1(X,Y), I(X,Y) \right]$



I(X,Y) - Drain current (linear region)

I1(X,Y) - Drain current (saturation region)

I2(X,Y) - Drain current

CHARACTERISTICS of MOSFET : W=700 um,L=100 um (33)

$Q := 1.6 \cdot 10^{-19}$ [Electron charge (Coulomb)]

$\mu := 1360$ [Electron mobility (cm2/volt*sec)]

$\epsilon s := 1.04 \cdot 10^{-12}$ [Si permittivity]

$Eafs := 4.23$ [Electron affinity (Volts)]

$Wfm := 4.2$ [Work function of Al (Volts)]

$Eg := 1.12$ [Band gap energy of Si]

$Kb := 1.38 \cdot 10^{-23}$ [Boltzman constant (J/K)]

$T := 300$ [Room temparature (Kelvin)]

$Na := 1.0 \cdot 10^{15}$ [Substrate concentration (cm(-3))]

$ni := 1.5 \cdot 10^{10}$ [Intrinsic concentration (cm(-3))]

$$Wms := Wfm - \left[Eafs - \frac{Eg}{2} - Kb \cdot T \cdot \ln\left[\frac{ni}{Na}\right] \right] \qquad Wms = 0.53$$

[Wms - Work function difference (Volts)]

$$\phi b := \frac{Kb \cdot T \cdot \ln\left[\frac{Na}{ni}\right]}{Q} \qquad \phi b = 0.287 \quad \text{[Volts]}$$

$Qss := 6.3 \cdot 10^{11}$ [Interface state density (cm(-2))]

$A := .0025$ [Gate area (cm2)]

$Cox := 86.25 \cdot 10^{-12}$ [Oxide capacitance (Farad)]

$$Coxa := \frac{Cox}{A}$$ [Farad/cm2]

[Coxa - Oxide capacitance per unit area]

$$Vfb := Wms - \frac{Qss \cdot Q}{Coxa} \qquad Vfb = -2.392 \quad [Volts]$$

[Vfb - Flat-band voltage]

$$\Gamma := \frac{\sqrt{2 \cdot \epsilon s \cdot Q \cdot Na}}{Cox} \cdot A \qquad \Gamma = 0.529$$

[Γ - Body-effect parameter]

$$Vth := Vfb + 2 \cdot \phi b + \Gamma \cdot \sqrt{2 \cdot \phi b}$$

Vth = -1.416 [Volts]

[Vth - Threshold voltage]

Wq := 700 [Width of gate (um)]

Leff := 100 [Lenght of gate (um)]

$$\beta := \frac{\mu \cdot Coxa \cdot Wq}{Leff} \qquad \beta = 3.284 \cdot 10^{-4}$$

$$Idss := \frac{\beta}{2} \cdot (0 - Vth)^2 \qquad Idss = 3.293 \cdot 10^{-4}$$

[Idss - Drain current at zero gate bias (Amp)]

Vga := 0.33

[Vga - Gate voltage at Ids=500 uA (Volts)]

$$Gm := \beta \cdot (Vga - Vth) \qquad Gm = 5.735 \cdot 10^{-4}$$

[Gm - Transconductance (mhos)]

Vgs := 1.0 [Starting gate voltage (Volts)]

X := 0 ..10

Vg_X := Vgs + (X · 1.0) [Gate voltage (Volts)]

Vds := 0 [Starting drain-source voltage (Volts)]

Y := 0 ..100

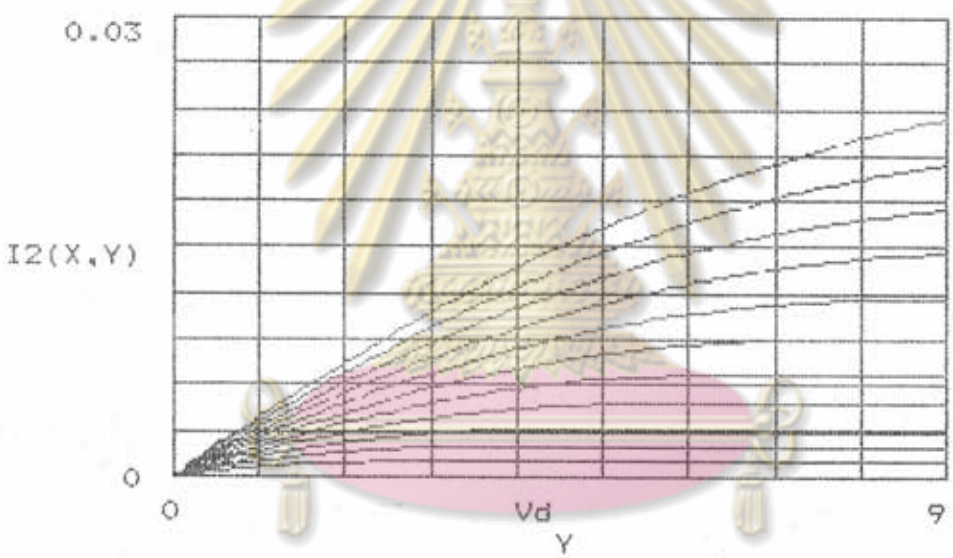
$Vd_Y := Vds + (Y \cdot 0.1)$ [Drain-source voltage (Volts)]

$$I(X,Y) := \beta \cdot \left[\left[Vg_X - Vth \right] \cdot Vd_Y - \frac{Vd_Y^2}{2} \right]$$

$$I1(X,Y) := \frac{\beta}{2} \left[Vg_X - Vth \right]^2$$

$Vdssat_X := Vg_X - Vth$

$I2(X,Y) := if\left[Vd_Y \geq Vdssat_X, I1(X,Y), I(X,Y) \right]$



I(X,Y) - Drain current (linear region)

I1(X,Y) - Drain current (saturation region)

I2(X,Y) - Drain current

$Gm50 := 8.106 \cdot 10^{-4}$ [mho] $Gm75 := 6.617 \cdot 10^{-4}$ [mho]

$Gm100 := 5.735 \cdot 10^{-4}$ [mho]

$$A := \frac{Gm50}{Gm100} \qquad A = 1.413$$

$$B := \frac{Gm75}{Gm100} \qquad B = 1.154$$

ประวัติผู้เขียน

นายธนวิชญ์ ชุลิกาวิทย์ เกิดเมื่อวันที่ 3 กุมภาพันธ์ 2505 ณ จังหวัดสระบุรี สำเร็จการศึกษาปริญญาวิศวกรรมศาสตร์บัณฑิต สาขาวิศวกรรมไฟฟ้า จากคณะวิศวกรรมศาสตร์ มหาวิทยาลัยเชียงใหม่ เมื่อปี พ.ศ. 2528 หลังจากนั้นได้เข้ารับราชการที่คณะวิศวกรรมศาสตร์ มหาวิทยาลัยเชียงใหม่ เป็นเวลา 1 ปี จึงลาศึกษาต่อในระดับปริญญามหาบัณฑิต ณ คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย