

N71-34416

**CASE FILE
COPY**

PROFILING PROCEDURES

- I. Anodic Oxidation
- II. OLS-Profile-Program

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The instructions in the following sections enable the reader to use the anodic oxidation apparatus in conjunction with OLS-PROFILE-PROGRAM to obtain electrically active concentration profiles of doped silicon wafers. Anodic oxidation technique is used here to grow SiO_2 (at room temperature) on a silicon wafer which has been previously doped with p or n type impurities. A subsequent etching of oxide is made which also removes a thin layer of doped silicon which has reacted with oxygen to form above oxide. Next a four point probe measurement of V/I (keeping I at 1ma always) is made on the surface of silicon. The above procedure is repeated until enough layers of doped silicon are removed so that a change from doped impurity type to substrate impurity type has occurred. This change is detected by performing the hot point probe test at the end of each run.

After a complete set of data (i.e. oxide thicknesses and voltage readings) is obtained in the above manner, this information is fed into the OLS (see part II). OLS is programmed to calculate and display both numerical values and the curves of impurity concentration, mobility, and total amount of impurities which have been depleted at each point along the profile. In the last stage, after a specified number of profiles of different dopings have been obtained, the computer displays them collectively on screen. This display facilitates the comparison and analysis of a set of profiles in relation to each other.

I. ANODIC OXIDATION

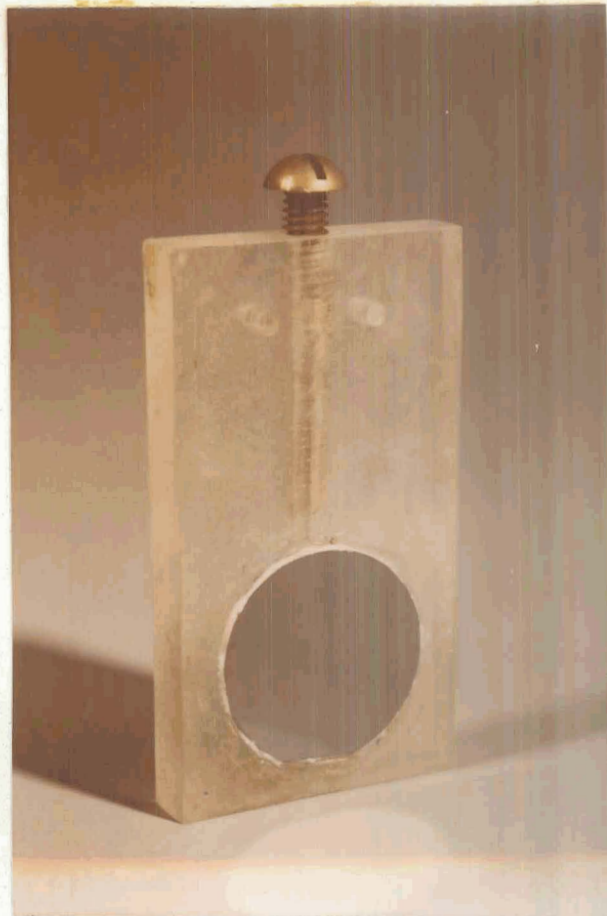
PROCEDURE

1. Put on white overall and gloves.
2. Clean up Si Wafer:

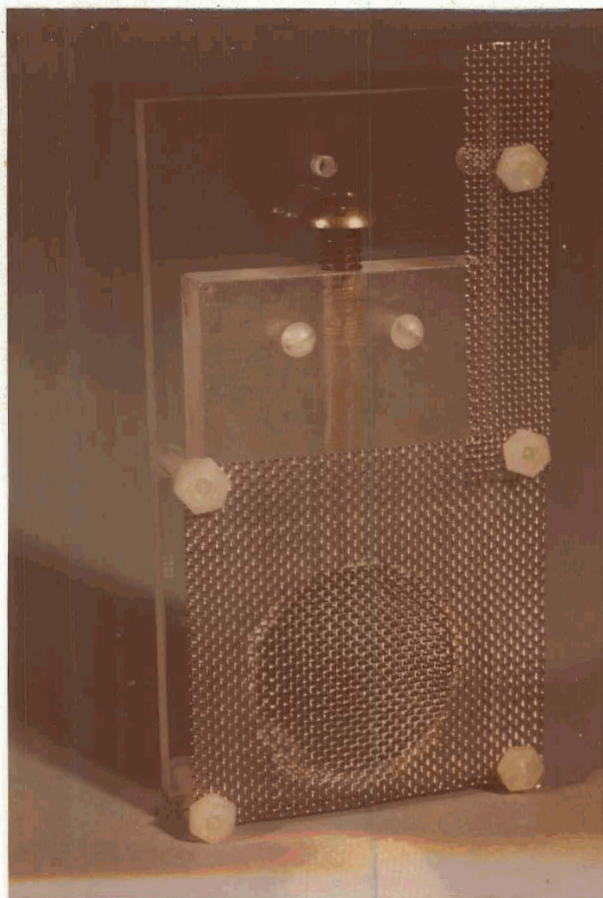
As indicated in manual or posted on hood.
3. Clean the wafer holder completely:
 - A. Remove all RTV from the previous run.
 - B. Use a cotton swab and TCE to clean Hg channel thoroughly. Role the swab in a paper towel and discard!
 - C. Wash holder under D.I. (Deionized) water.
 - D. Use a paper towel to dry outside and use air pressure to dry the inside of Hg channel.
4. Take wafer and the holder to the Lapping Room and apply RTV as shown in Fig. 1.b.
 - A. RTV may have dried at the tip of its container. This dried section should be removed and only the fresh RTV used.
 - B. Do not allow excess RTV to plug the contacting hole; but apply enough RTV so that the back of the wafer will be tightly attached to the holder.
5. Place the wafer on top of the RTV and press very gently around the edges of wafer. Once the wafer is properly attached to the holder, cover the edges with more RTV (hence, blocking any Hg from slipping from the corners).



(a)



(b)



(c)



(d)

Fig. 1 Anodic Oxidation Apparatus

6. Allow RTV to dry for 15 minutes under heat gun which is placed at approximately 2 ft. from the wafer.

7. Clean the undesired RTV from the Si surface by rubbing gently with a cotton swab (dipped in TCE) on the Si surface.

Check the hole on the back of the wafer and make sure that the RTV has not covered the back of the Si Wafer (hence, preventing electrical connection of Si with Hg which is to be added next).

8. Screw on tightly the plastic screw in the hole located on the back of the wafer holder.

9. Add Hg from the top hole:

Using the eyedropper that has been provided, very carefully draw some Hg from the container and add to the top hole.

CAUTION: This step should be performed under the hood in the stainless steel box and with great care. Note that Hg is poisonous and hard to clean.

If any Hg is dropped, be sure to pick it up completely, using the eyedropper.

10. Fill approximately half of a 600 ml beaker with electrolytic solution (15 grams potassium nitrate dissolved in 1 gallon ethylene glycol by spinning for 24 hours). Place a clean screen apparatus in the beaker and see that solution covers the square portion of the screen.

11. Insert the holder into the screen apparatus in the electrolytic solution and insert the connector into the Hg channel (Fig. 1.c.).
12. Put the beaker into the ultrasonic vibrator and turn it on.
(Cover the remaining area of ultrasonic vibrator with its top)
13. Connect the positive-potential clip to the wire inserted into the Hg and connect the negative-potential clip to the screen.
14. Turn on constant current supply.
15. Set current monitor to 30 ma.
16. Set voltage monitor to V.REF. (Reference Voltage)
17. Set reference voltage to 200V by adjusting REF.ADJ. knob.
18. Switch back voltage monitor to V.OUT.
19. Push the reset knob and observe output voltage rising on the meter.
20. Check the constant current flow by pressing the red knob occasionally.
21. Once the output voltage reaches reference voltage, supply shuts itself off.
22. Turn off supply manually.
23. Turn off ultrasonic vibrator.
24. Take the positive wire out of the Hg channel and place it in the stainless steel container.
25. Screw the top hole tight in order to avoid spillage of Hg in the next few steps.

26. Take the holder out of the solution and wipe off the excess solution on the holder with a paper towel.
27. Blow air over the wafer until the color of the oxide shows.
28. Compare color with the color chart and mark oxide thickness.
29. Take the wafer to the HF hood and put a few drops of buffered HF on the wafer with a cotton swab, allow 30 sec. and then wash with D.I. water thoroughly.

CAUTION: Be sure to wear gloves and to keep them dry and clean.

Don't allow any chemicals, especially HF, on your hands. Wash your gloves with soap and water at this point and dry them.

30. Dry holder and wafer with air thoroughly.
31. Take wafer to four-point probe station and measure $\frac{V}{I}$: V(top meter), I (bottom meter, which should be set at 1 ma. always).
32. Take wafer to the hot probe station and test for p or n type. (Enter above results in proper column.)
33. Take back the holder to the anodic oxidation station and remove the safety screw from top of Hg channel.
34. Repeat steps 11 through 33 until the hot point probe indicates complete reversal in the impurity type.
35. At the end of your work, take screen apparatus out of the beaker and wash under D.I. water and dry. Cover the solution in the beaker and place everything in the stainless steel box under the hood.

Now you are ready to feed above data into the OLS and obtain profiles. See instructions on how to use OLS-Profile-Program.

II. OLS-PROFILE-PROGRAM

PRESS THE FOLLOWING
KEYS IN SEQUENCE

CORRESPONDING
DISPLAY

Scope Turn on Procedure:

An underline means a
button press.

- 1) ON (located on scope)
- 2) ERASE (located on scope)

Wait until display
is bright green
Screen is cleared

OLS Turn on Procedure:

- 1) SYST
- 2) 7 7 RETURN
- 3) E E 2 3 0 RETURN
- 4) O R D U N G RETURN
- 5) P R O F I L E RETURN
- 6) P F RETURN

ENTER USER NUMBER

77

ID NUMBER =

USER NAME =

ORDUNG

JOB NAME =

PROFILE

AUTOSAVE CODE 1, 2 etc.

LOAD

FILE LOADED

Turn off Procedure:

- 1) SYST
- 2) V
- 3) OFF (located on scope)

WORK AREAS UPDATED

WORK AREAS PURGED

Display is turned off.

PRESS THE FOLLOWING
KEYS IN SEQUENCE

CORRESPONDING
DISPLAY

OLS-Profile-Program:

- (1) Turn on Scope and OLS
(see previous page)

(2) USER LII REFL

1

(3) P or N ENTER

2

This step selects the
proper mobility vs.

conc. data: P for hole
mobility (from 500 to
45 $\frac{\text{cm}^2}{\text{sec. volt}}$) and N for

electron mobility (from
1350 to 82 $\frac{\text{cm}^2}{\text{sec. volt}}$)

vs. total impurity

concentration (from 10^{12}
to 10^{22} cm^{-3})

Upon the correct display
of impurity type press

(4) ENTER

3

or

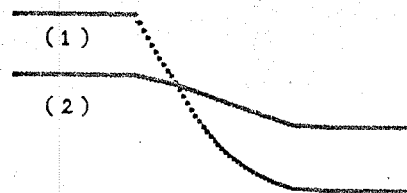
4

ENTER IMPURITY TYPE

DISPLAY 1

ENTER IMPURITY TYPE P

DISPLAY 2



(1) HOLE MOBILITY VS.
TOTAL IMPURITY CONCENTRA-
TION (LOG).
(2) HOLE MOBILITY (LOG)
VS. TOTAL IMPURITY CON-
CENTRATION (LOG).

DISPLAY 3

PRESS THE FOLLOWING
KEYS IN SEQUENCE

CORRESPONDING
DISPLAY

(5) ENTER

5

Enter the number of
profiles on the key-
board, e.g. 2

(6) ENTER

6

(Check the desired
number of profiles
displayed; otherwise
make correction by
pressing
USER LI MOD and repeat
steps (5) and (6)).

(7) ENTER

7

Enter the number of
points on the keyboard,
e.g. 16

(8) ENTER

8

If number of points
displayed is not
correct press USER
LI , enter the
correct number and
press ENTER.



(1) ELECTRON MOBILITY
VS. TOTAL IMPURITY CON-
CENTRATION (LOG).
(2) ELECTRON MOBILITY
(LOG) VS. TOTAL IMPURITY
CONCENTRATION (LOG).

DISPLAY 4

ENTER NO. OF PROFILES,

DISPLAY 5

ENTER NO. OF PROFILES, 2

DISPLAY 6

PRESS THE FOLLOWING
KEYS IN SEQUENCE

CORRESPONDING
DISPLAY

(9) ENTER

Enter voltage reading
(in volts) on the
keyboard e.g. 3 . 7 0 4

(10) ENTER

9

Above voltage should
appear on screen. If
not, make correction
by pressing USER LI @,
entering correct voltage
and pressing ENTER.

If the display is
correct press ENTER
again. Continue enter-
ing all voltage readings
by repeating steps (9)
and (10)

10

Press ERASE when the last
line on scope is used.

Scope will continue
display from the top of
the screen.

After the last entry,
"ENTER OXIDE THICKNESS
READINGS (CM)" is
displayed.

11

PRØFILE 1
ENTER NØ. ØF PØINTS,

DISPLAY 7

PRØFILE 1
ENTER NØ. ØF PØINTS, 16
ENTER VØLTAGE READINGS,

DISPLAY 8

PRØFILE 1
ENTER NØ. ØF PØINTS, 16
ENTER VØLTAGE READINGS,
1) 3.704 +00

DISPLAY 9

PRØFILE 1
ENTER NØ. ØF PØINTS, 16
ENTER VØLTAGE READINGS,
1) 3.704 +00
2) 4.2 +00
3) 5. +00
4) 6. +00
5) 6.9 +00
6) 8.5 +00
7) 1.05 +01
8) 1.34 +01
9) 1.65 +01
10) 2.15 +01
11) 3. +01
12) 4.1 +01
13) 6.4 +01

DISPLAY 10

PRESS THE FOLLOWING
KEYS IN SEQUENCE

CORRESPONDING
DISPLAY

(11) Repeat steps (9) and
(10) as discussed above
but this time enter oxide
thicknesses instead of
voltage readings. Note:
Always enter zero for the
first oxide thickness
reading. After entering
the last oxide thickness
check to see all correct
information is entered,
if any mistakes are made
start over from step (7)
by pressing USER LI @

12

Note: In Display 12 after
line 13) an error message,
"SUBSCRIPT OVERFLOW" is
written. This message
usually appears using an
old keyboard where upon
pressing a number once
actually that number
is entered many times,
(due to unstable button
contact).

14)	1.1	+02
15)	3.5	+02
16)	8.7	+02

ENTER OXIDE THICKNESS
 READINGS (CM),

1)	0.	+00
2)	9.	-06
3)	9.	-06
4)	7.515	-06
5)	7.02	-06
6)	5.895	-06
7)	5.94	-06
8)	5.85	-06
9)	3.915	-06
10)	3.915	-06
11)	4.185	-06

DISPLAY 11

12)	3.915	-06
13)	4.1175	-06

SUBSCRIPT OVERFLOW

14)	4.275	-06
15)	6.4575	-06
16)	5.4	-06

DISPLAY 12

PRESS THE FOLLOWING

CORRESPONDING

KEYS IN SEQUENCE

DISPLAY

(11) continued

This series entry, when exceeds the allocated storage area in working register, causes the above message to appear. However, correction is made simply by entering the intended number again.

(12) ENTER

13

Wait

After calculations here

terminated screen is

erased and profiles

(both linear conc. and

log. conc.) are dis-

played with vertical

and horizontal scales

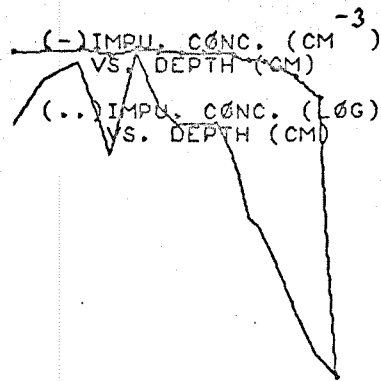
optimize for best display.

14

CALCULATIONS IN PROCESS
WAIT

DISPLAY 13

(-) IMPU. CONC. (CM⁻³)
VS. DEPTH (CM)
(..) IMPU. CONC. (LOG)
VS. DEPTH (CM)



DISPLAY 14

PRESS THE FOLLOWING

CORRESPONDING

KEYS IN SEQUENCE

DISPLAY

(13) ENTER

15

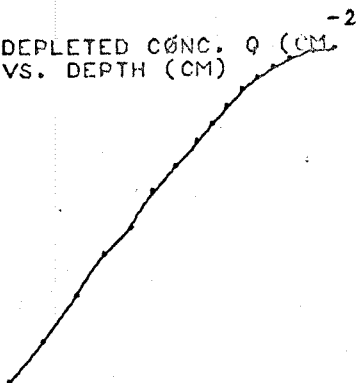
In this step the area under previous profile is integrated and the result is displayed. Physically each point shows the total impurity per unit area which has been taken away from silicon up to that point by repeated oxidation and etching.

(14) ENTER

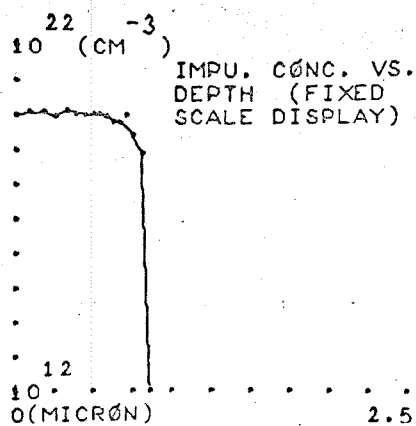
16

Same as Display 14 except here the scale is fixed. Impurity concentration (LOG):
 10^{12} to 10^{22} (cm⁻³)
Depth into wafer:
0 to 2.5 μ

DEPLETED CONC. Q (CM⁻²)
VS. DEPTH (CM)



DISPLAY 15



DISPLAY 16

PRESS THE FOLLOWING

CORRESPONDING

KEYS IN SEQUENCE

DISPLAY

(15) ENTER

17

Numerical values of depth
and concentration corre-
sponding to each point on
profile (Display 14 or 16)
are shown.

18

Note: Since there are
more numerical values than
maximum lines available on
scope the program is
modified to stop display
after the last possible
line is written. Conse-
quently information PRESS
ERASE AND ENTER is shown
(Display 17) indicating
that there are more values
which will be written after
pressing ERASE and ENTER
(Display 18)

Note: In Display 17, eighth
line, the 2 of exponent +20
has jumped to top of the
display next to -3. This is
caused by the scope malfunction-
ing.

2-3

DEPTH (CM) , CONC. (CM)

0.	+00,	1.09105+20
9.	-06,	1.30363+20
1.8	-05,	1.36608+20
2.5515	-05,	9.51776+19
3.25349	-05,	1.42526+20
3.84299	-05,	1.16188+20
4.43699	-05,	1.08511+ 0
5.02199	-05,	1.10298+20
5.41349	-05,	1.10877+20
5.80499	-05,	9.68534+19
6.22349	-05,	6.91974+19
6.61499	-05,	6.42549+19
7.02674	-05,	4.54167+19
7.45423	-05,	2.80599+19

PRESS ERASE AND ENTER

DISPLAY 17

8.09998	-05,	8.35277+18
8.63998	-05,	9.99991+11

DISPLAY 18

PRESS THE FOLLOWING
KEYS IN SEQUENCE

CORRESPONDING
DISPLAY

(16) ENTER

19

The first column shows
the numerical values of
Q, total impurities
depleted up to each
point on profile.

20

Second column shows
mobilities corresponding
to concentrations along
the profile.

Note: The last mobility
value in the 2nd column is
a negative value which
obviously is not correct.
This information is useful
to determine if at any point
along the profile concen-
tration actually has fallen
below $10^{12}(\text{cm}^{-3})$ which is
the minimum concentration
possible to be displayed.

C, (CM⁻²) , MOBILITY

0.	+00,	4.5	+01
9.8195	+14,	4.5	+01
2.15522	+15,	4.5	+01
3.18183	+15,	4.50932	+01
3.84998	+15,	4.5	+01
4.6902	+15,	4.5	+01
5.3803	+15,	4.5	+01
6.0151	+15,	4.5	+01
6.4469	+15,	4.5	+01
6.881	+15,	4.50597	+01
7.2864	+15,	4.57517	+01
7.5573	+15,	4.59159	+01
7.8218	+15,	4.66417	+01
8.016	+15,	4.76805	+01

PRESS ERASE AND ENTER

DISPLAY 19

8.1972	+15,	5.24725	+01
8.2423	+15,	-8.9949	+08

DISPLAY 20

PRESS THE FOLLOWING
KEYS IN SEQUENCE

CORRESPONDING
DISPLAY

(17) ENTER

21

In this step OLS checks to see if all profiles have been loaded. If not, the message shown in Display 21 appears. If all profiles have been loaded the message "PROFILES LOADED, PRESS ENTER TO COMPARE" appears (see step 19).

(18) ENTER and

22

continue to load the second set of data for the second profile. The steps to be followed are the same as steps (7) through step (16).

through

31

TO LOAD NEXT PROFILE
PRESS ENTER

DISPLAY 21

PROFILE 2

ENTER NO. OF POINTS, 16
ENTER VOLTAGE READINGS,

1)	4.	+00
2)	4.7	+00
3)	6.	+00
4)	6.9	+00
5)	7.85	+00
6)	1.	+01
7)	1.3	+01
8)	1.75	+01
9)	2.25	+01
10)	3.3	+01
11)	4.4	+01
12)	8.5	+01
13)	1.35	+02

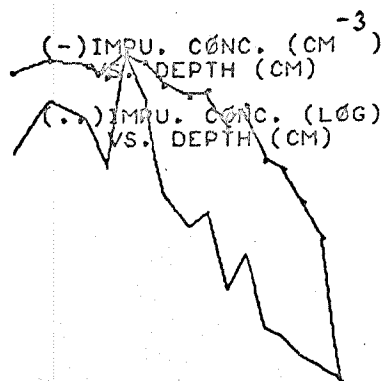
DISPLAY 22

14) 2.75 +02
 15) 7.5 +02
 16) 1.1 +04
 ENTER OXIDE THICKNESS
 READINGS (CM),
 1) 0. +00
 2) 8.1 -06
 3) 8.1 -06
 4) 4.14 -06
 5) 4.1175 -06
 6) 4.1625 -06
 7) 4.1625 -06
 8) 5.355 -06
 9) 4.1175 -06
 10) 4.1175 -06
 11) 4.1175 -06

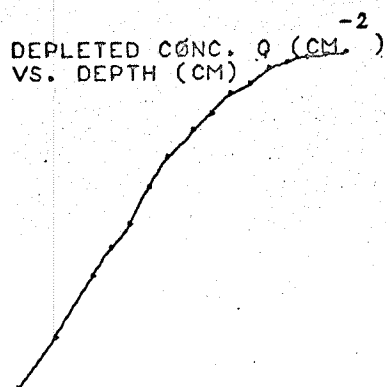
DISPLAY 23

12) 4.1625 -06
 13) 4.1175 -06
 14) 4.1175 -06
 15) 4.365 -06
 16) 4.0151 -06

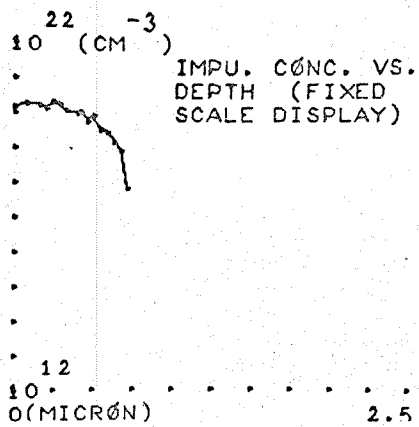
DISPLAY 24



DISPLAY 25



DISPLAY 26



DISPLAY 27

DEPTH (CM) , CONC. (CM)²⁻³

0.	+00,	1.41573+20
8.1	-06,	1.75281+20
1.62	-05,	1.61722+20
2.034	-05,	1.31189+20
2.44575	-05,	2.02648+20
2.86199	-05,	1.70746+20
3.27824	-05,	1.13762+ 0
3.81374	-05,	9.47688+19
4.22549	-05,	1.05775+20
4.63724	-05,	5.51595+19
5.04899	-05,	8.03067+19
5.46524	-05,	3.08896+19
5.87699	-05,	2.65521+19
6.28874	-05,	1.48972+19

PRESS ERASE AND ENTER

DISPLAY 28

6.72523-05,	8.10098+18
7.12674-05,	6.52881+17

DISPLAY 29

-2

μ, (CM⁻²), MOBILITY

0.	+00,	4.5	+01
1.14674	+15,	4.5	+01
2.56653	+15,	4.5	+01
3.23606	+15,	4.5	+01
3.77623	+15,	4.5	+01
4.6198	+15,	4.5	+01
5.3305	+15,	4.5	+01
5.9397	+15,	4.51015	+01
6.3299	+15,	4.5	+01
6.7654	+15,	4.62287	+01
6.9925	+15,	4.54513	+01
7.3268	+15,	4.74802	+01
7.454	+15,	4.78046	+01
7.5633	+15,	4.90853	+01

PRESS ERASE AND ENTER

DISPLAY 30

7.6284	+15,	5.2939	+01
7.6609	+15,	1.05302	+02

DISPLAY 31

PRESS THE FOLLOWING
KEYS IN SEQUENCE

CORRESPONDING
DISPLAY

(19) ENTER

32

This step is similar
to step (17); however,
the message displayed
indicates that at this
point all profiles are
loaded and ready for
comparison.

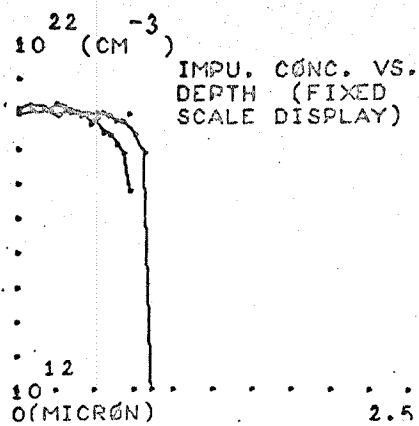
(20) ENTER

33

Simultaneous display
of all concentration
profiles loaded (fixed
scale).

PROFILES LOADED, PRESS
ENTER TO COMPARE

DISPLAY 32



DISPLAY 33

PRESS THE FOLLOWING
KEYS IN SEQUENCE

CORRESPONDING
DISPLAY

(21) ENTER

34

"END"

If the program is to be used again for a new set of profiles having the same type of impurities as the previous set, just press USER LI MOD and repeat the above procedure starting at step (5). However, if the impurities of the new set are different press USER LII REFL and begin at step (3). In either case, when a new set of profiles are loaded, all the data and results of the previous set are erased.

At the end of your work do not forget to turn off the OLS and the scope as shown on the first page of this OLS procedure. Every hour that the system remains on it costs the department \$6.50!!!!

END

DISPLAY 34