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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.

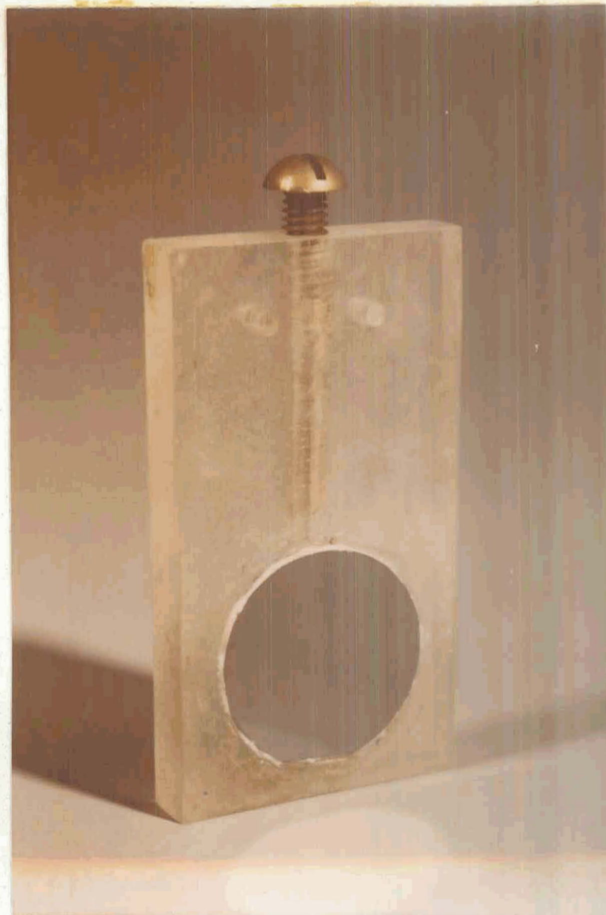
4. Take wafer and the holder to the Lapping Room and apply RTV as shown in Fig. 1.b.

   A. RTV may have dried at the tip of its container. This dried section should be removed and only the fresh RTV used.

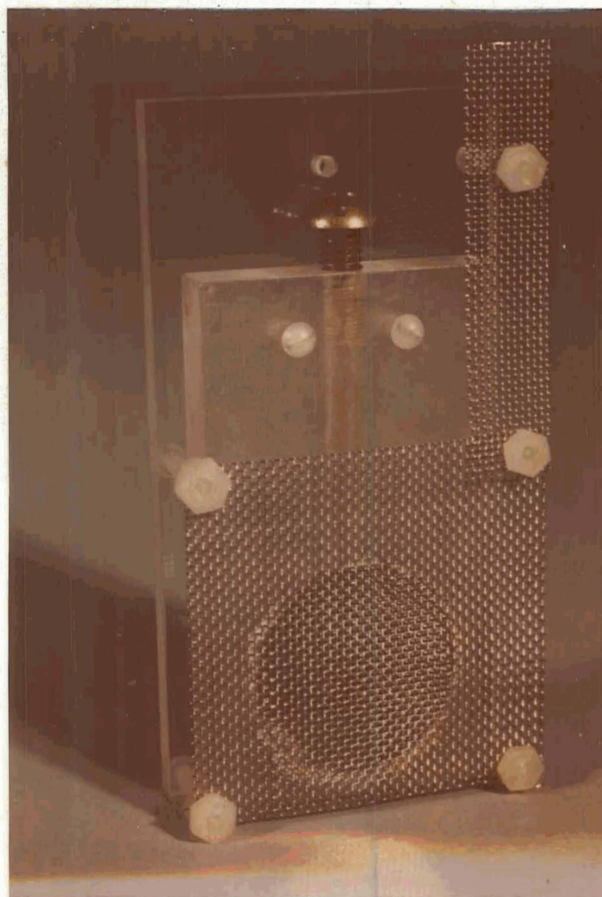
   B. Do not allow excess RTV to plug the contacting hole; but apply enough RTV so that the back of the wafer will be tightly attached to the holder.

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 mannually.

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 abcve 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)	Wait until display is bright green
2) ERASE (located on scope)	Screen is cleared
OLS Turn on Procedure:	
1) SYST	ENTER USER NUMBER
2) 7 7 RETURN	77
	ID NUMBER =
3) E E 2 3 0 RETURN	USER NAME =
4) O R D U N G RETURN	ORDUNG
	JOB NAME =
5) P R O F I L E RETURN	PROFILE
	AUTOSAVE CODE 1, 2 etc.
	LOAD
6) P F RETURN	FILE LOADED
Turn off Procedure:	
1) SYST	WORK AREAS UPDATED
2) ↓	WORK AREAS PURGED
3) OFF (located on scope)	Display is turned off.

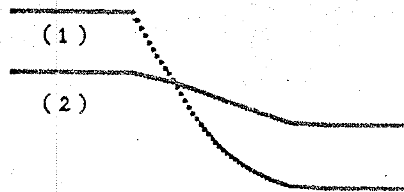
PRESS THE FOLLOWING KEYS IN SEQUENCE	CORRESPONDING DISPLAY
OLS-Profile-Program:	
(1) Turn on Scope and OLS (see previous page)	
(2) USER LII REFL	1
(3) P or N ENTER This step selects the proper mobility vs. conc. data: P for hole mobility (from 500 to 45 $\frac{cm^2}{sec.\ volt}$) and N for electron mobility (from 1350 to 82 $\frac{cm^2}{sec.\ volt}$) vs. total impurity concentration (from 10^{12} to 10^{22} cm^{-3}) Upon the correct display of impurity type press	2
(4) ENTER	3 or 4

ENTER IMPURITY TYPE

DISPLAY 1

ENTER IMPURITY TYPE P

DISPLAY 2



(1) HØLE MØBILITY VS. TØTAL IMPURITY CØNCENTRATIØN (LØG).
(2) HØLE MØBILITY (LØG) VS. TØTAL IMPURITY CØNCENTRATIØN (LØG).

DISPLAY 3

PRESS THE FOLLOWING KEYS IN SEQUENCE	CORRESPONDING DISPLAY
(5) ENTER Enter the number of profiles on the key-board, e.g. 2	5
(6) ENTER (Check the desired number of profiles displayed; otherwise make correction by pressing USER LI MOD and repeat steps (5) and (6)).	6
(7) ENTER Enter the number of points on the keyboard, e.g. 16	7
(8) ENTER If number of points displayed is not correct press USER LI ⊖, enter the correct number and press ENTER.	8

(1) ELECTRØN MØBILITY VS. TØTAL IMPURITY CØN-CENTRATIØN (LØG).
(2) ELECTRØN MØBILITY (LØG) VS.TØTAL IMPURITY CØNCENTRATIØN (LØG).

DISPLAY 4

ENTER NØ. ØF PRØFILES,

DISPLAY 5

ENTER NØ. ØF PRØFILES, 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 entering 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 ØXIDE 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

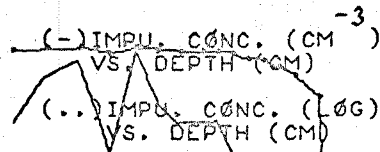
```
 12)  3.915   -06
 13)  4.1175  -06
SUBSCRIPT ØVERFLØW
 14)  4.275   -06
 15)  6.4575  -06
 16)  5.4     -06
```

DISPLAY 12

PRESS THE FOLLOWING KEYS IN SEQUENCE		CORRESPONDING 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)	<u>ENTER</u>	13
	Wait After calculations here terminated screen is erased and profiles (both linear conc. and log. conc.) are displayed with vertical and horizontal scales optimize for best display.	14

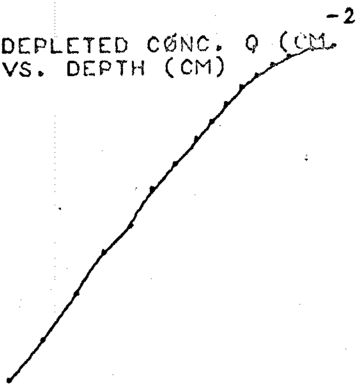
CALCULATIØNS IN PRØCESS
WAIT

DISPLAY 13

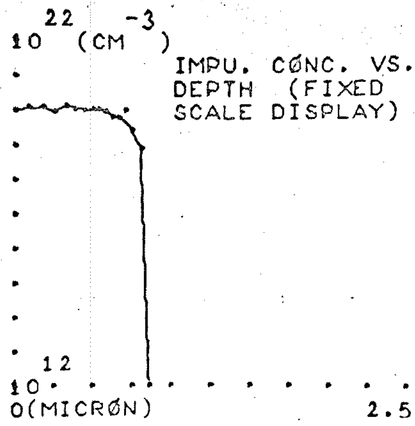


DISPLAY 14

PRESS THE FOLLOWING KEYS IN SEQUENCE	CORRESPONDING DISPLAY
(13) ENTER 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.	15
(14) ENTER 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	16



DISPLAY 15



DISPLAY 16

PRESS THE FOLLOWING KEYS IN SEQUENCE	CORRESPONDING DISPLAY
(15) ENTER	17
Numerical values of depth and concentration corresponding 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. Consequently 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 malfunctioning.	

```
                              2-3
ᴱPTH (CM) , CØNC. (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. 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 concentration actually has fallen below $10^{12}(cm^{-3})$ which is the minimum concentration possible to be displayed.	20

```
          -2
C, (CM  ) , MØBILITY

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 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).	21
(18) ENTER and 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).	22 through 31

```
TØ LØAD NEXT PRØFILE
PRESS ENTER
```

DISPLAY 21

```
         PRØFILE  2

ENTER NØ. ØF PØINTS,  16
ENTER VØLTAGE 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

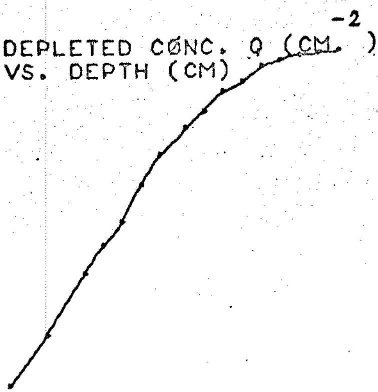
```
 14)  2.75    +02
 15)  7.5     +02
 16)  1.1     +04
ENTER ØXIDE THICKNESS
READINGS (CM),
 1)  0.      +00
 2)  8.1     -06
 3)  8.1     -06
 4)  4.14    -06
 5)  4.1175  -06
 6)  4.1625  -06
 7)  4.1625  -06
 8)  5.355   -06
 9)  4.1175  -06
 10)  4.1175 -06
 11)  4.1175 -06
```

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

10^{22} (CM^{-3})

IMPU. CØNC. VS.
DEPTH (FIXED
SCALE DISPLAY)

10^{12}

0(MICRØN) 2.5

DISPLAY 27

```
                      2-3
ᒥPTH (CM) , CØNC. (CM    )

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
C, (CM   ) , MØBILITY

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

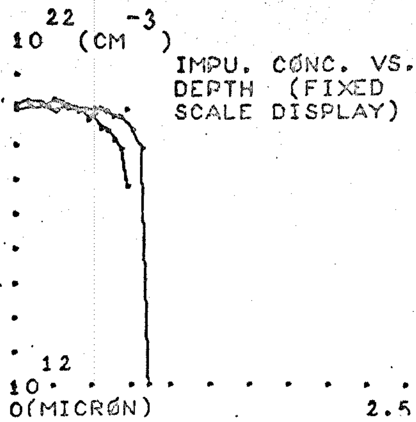
```
7.6284 +15, 5.2939 +01
7.6609 +15, 1.05302+02
```

DISPLAY 31

PRESS THE FOLLOWING KEYS IN SEQUENCE	CORRESPONDING DISPLAY
(19) ENTER This step is similar to step (17); however, the message displayed indicates that at this point all profiles are loaded and ready for comparison.	32
(20) ENTER Simultaneous display of all concentration profiles loaded (fixed scale).	33

PRØFILES LØADED, PRESS
ENTER TØ CØMPARE

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