Reducing Oxygen Flow Rate in the Bruce Furnace

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Abstract

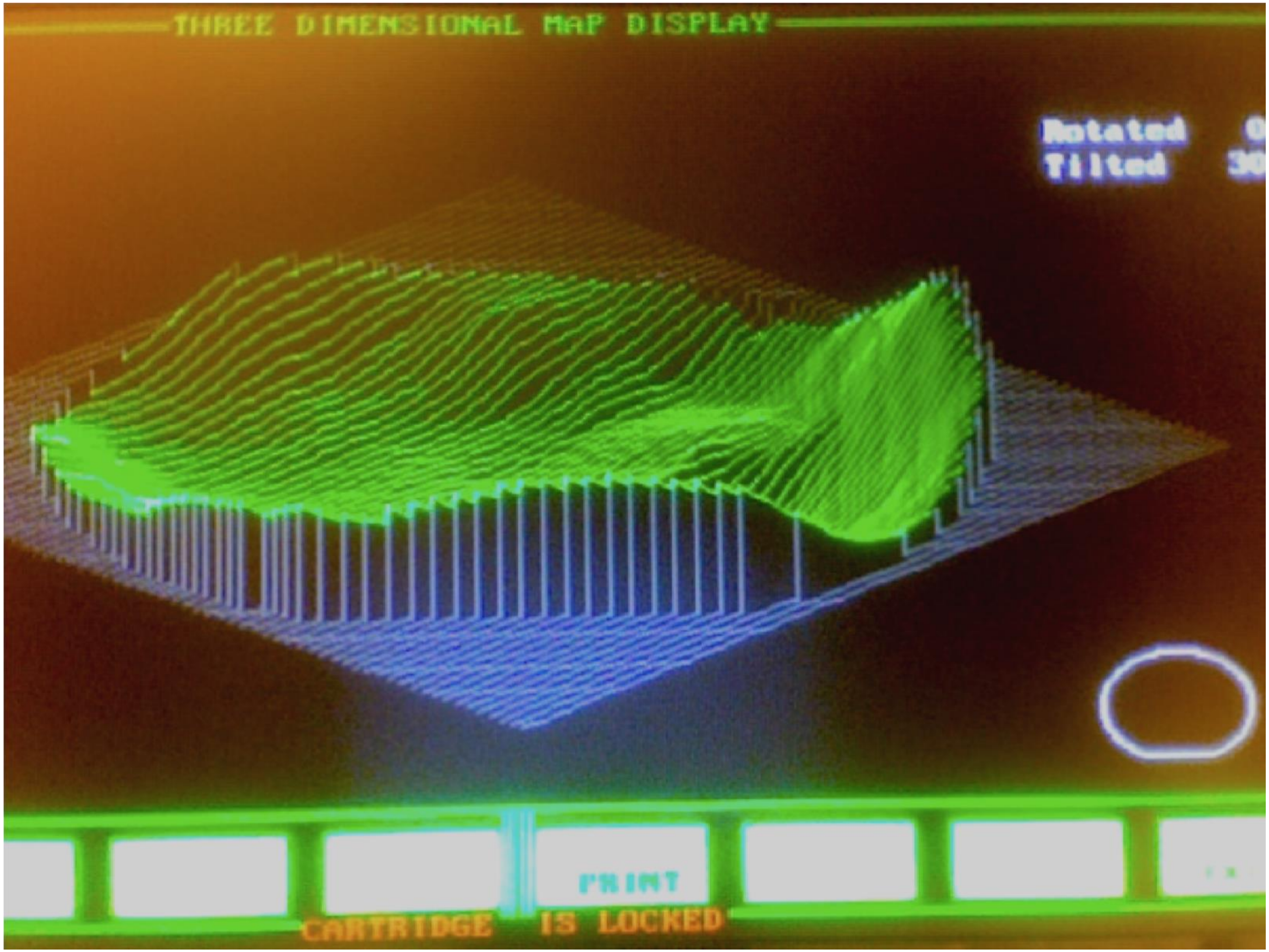
This experiment explored the usage of oxygen gas in the Bruce furnace. Since oxygen gas is used often in the growth of silicon dioxide, a method for reducing the amount of oxygen used in the Bruce Furnace is desired to reduce cost. We began with a recipe for 500Angstroms of oxide using a dry oxide process on clean wafers. We ran the recipe using an oxygen flow rate of 10L/min and then 5L/min and compared both the thickness and uniformity of oxide growth on the wafers. We then ran a similar experiment with a recipe for 1000Angstroms of oxide. The results showed that cutting the oxygen flow rate (and thereby the cost of oxygen for each run) in half had no affect on oxide thickness and uniformity.

Procedure

- Two bare wafers were placed in Tube 1 of the Bruce Furnace and recipe 250 was run for 500Angstroms of Dry Oxide.
- The wafers were measured with the Spectramap and data was recorded.
- The wafers were etched bare in BOE.
- Recipe 250 was altered, reducing the oxygen flow rate for the Soak period from 10L/min to 5L/min.
- The wafers were placed in Tube 1 and recipe 250, now altered, was run again.
- The wafers were measured with the Spectramap and data was recorded.
- Values for oxide thickness and uniformity were compared.

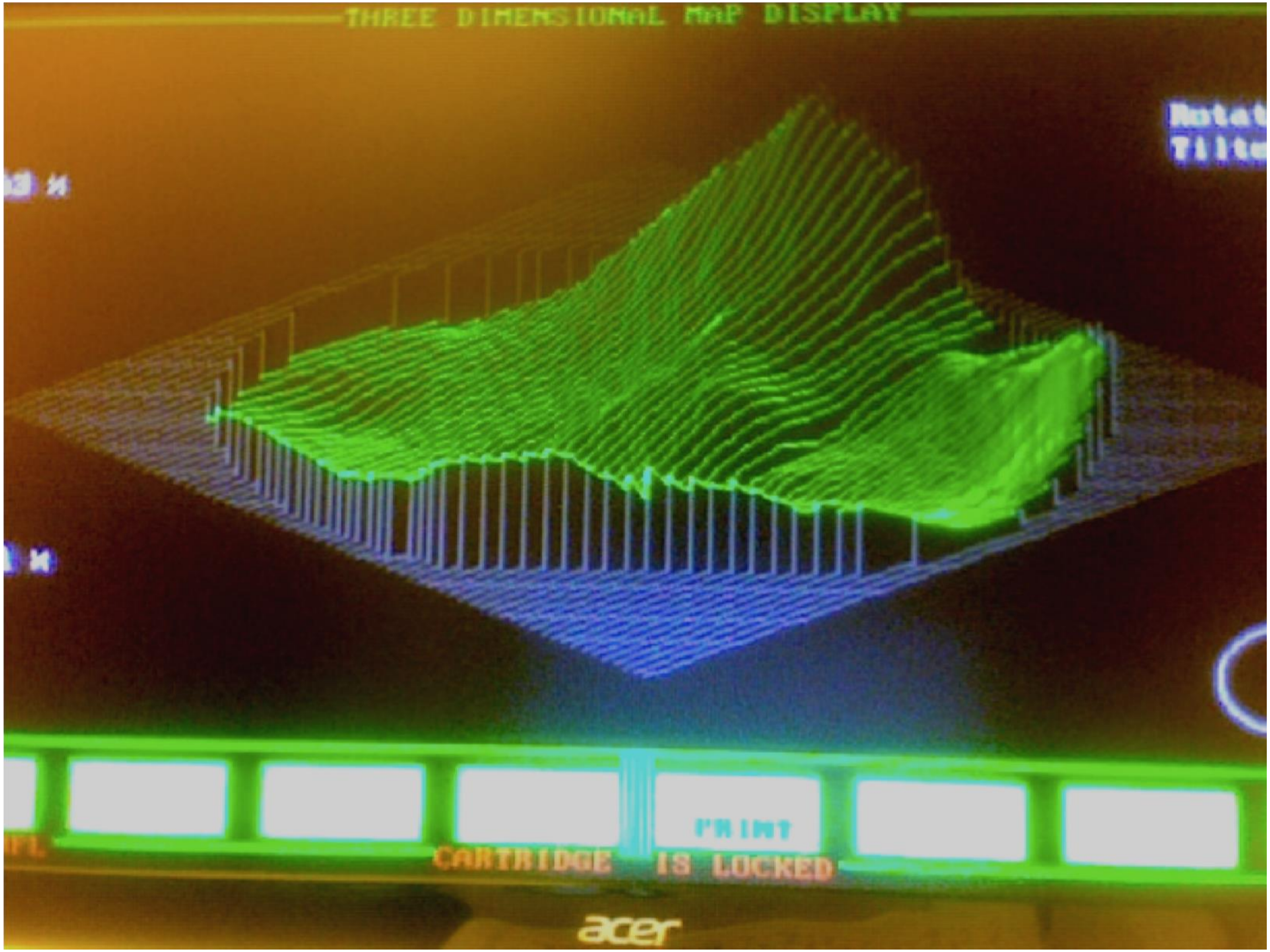
Wafer 1 Recipe 250 500A 10L/min 1000C

- Mean: 494.51
- Standard Deviation: 25.128 5.081%
- Minimum: 453.38
- Maximum: 573.97
- Range: 120.59
- # Sites/Good: 81/80


THREE DIMENSIONAL MAP DISPLAY
Rotated
Tilted
PRINT
CARTRIDGE IS LOCKED

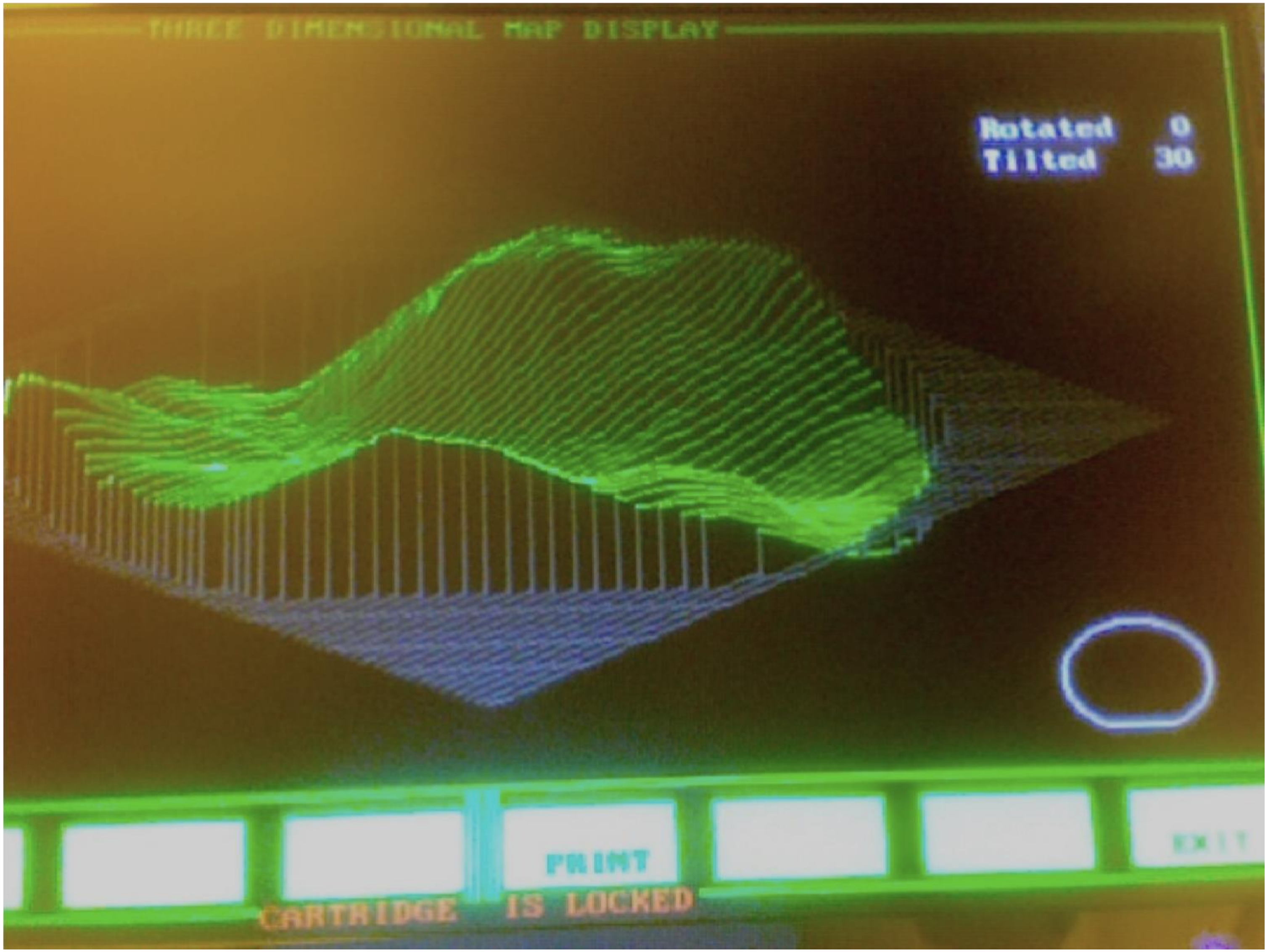
Wafer 2 Recipe 250 500A 10L/min 1000C

- Mean: 478.31
- Standard Deviation: 22.460   4.696%
- Minimum: 445.26
- Maximum: 543.51
- Range: 98.250
- # Sites/Good: 81/81


THREE DIMENSIONAL MAP DISPLAY
CARTRIDGE IS LOCKED
acer

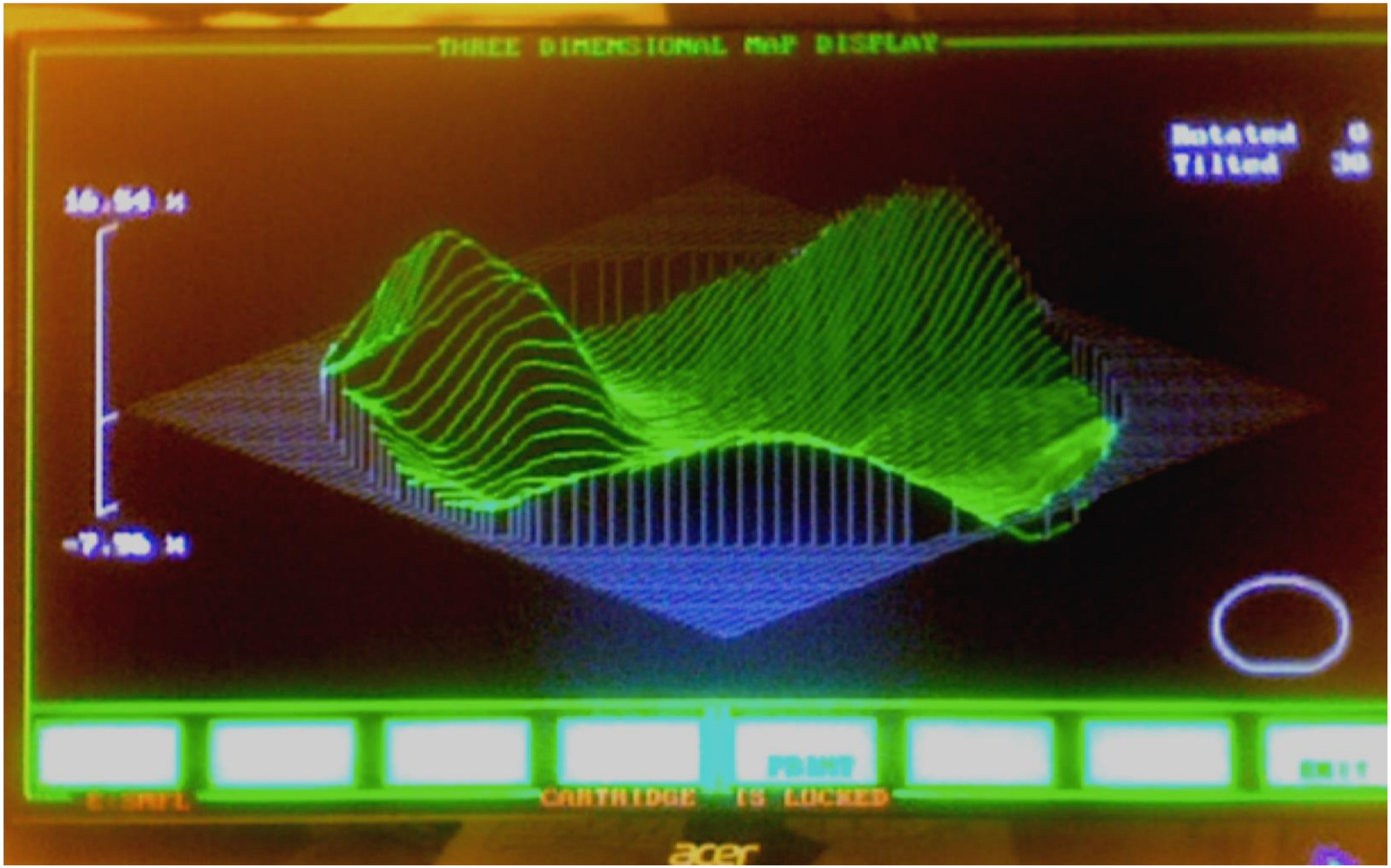
Wafer 1 Recipe 250 500A 5L/min 1000C

- Mean: 498.91
- Standard Deviation: 21.704 4.350%
- Minimum: 463.95
- Maximum: 555.40
- Range: 91.450
- #Sites/Good: 81/81


THREE DIMENSIONAL MAP DISPLAY
Rotated 0
Tilted 30
PRINT
CARTRIDGE IS LOCKED

Wafer 2 Recipe 250 500A 5L/min 1000C

- Mean: 522.54
- Standard Deviation: 30.002 5.74%
- Minimum: 480.94
- Maximum: 609.00
- Range: 128.06
- #Sites/Good: 81/81

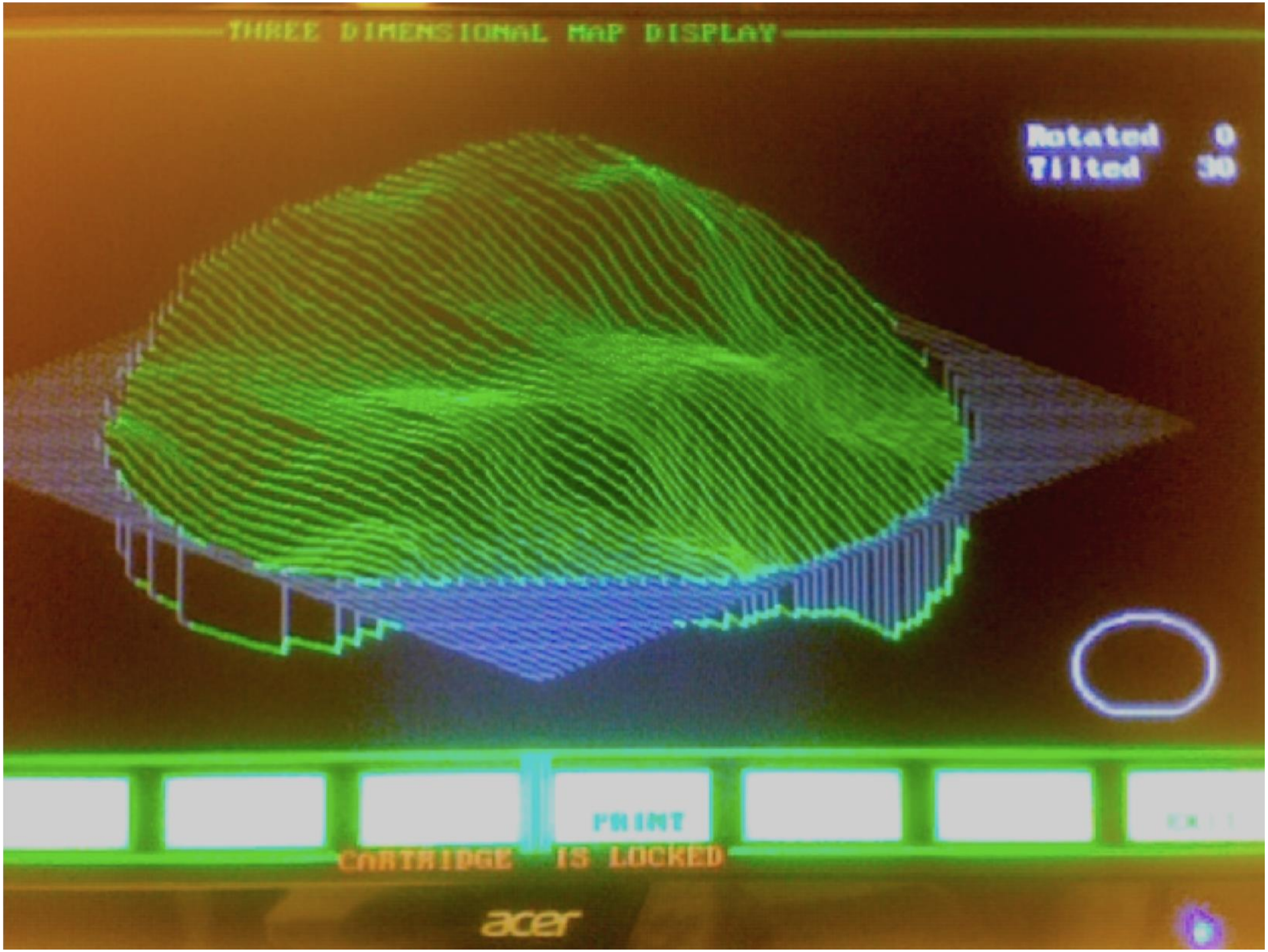

THREE DIMENSIONAL MAP DISPLAY
Rotated
Tilted
CARTRIDGE IS LOCKED

Comparison and Results

	10L/min	5L/min	10L/min	5L/min
	Wafer 1	Wafer 1	Wafer 2	Wafer 2
Mean	494.51	498.91	478.31	522.54
Standard Deviation	25.128 5.081%	21.704 4.350%	22.460 4.696%	30.002 5.74%
Min	453.38	463.95	445.26	480.94
Max	573.97	555.40	543.51	609.00
Range	120.59	91.450	98.250	128.06
#Sites/ Good	81/80	81/81	81/81	81/81

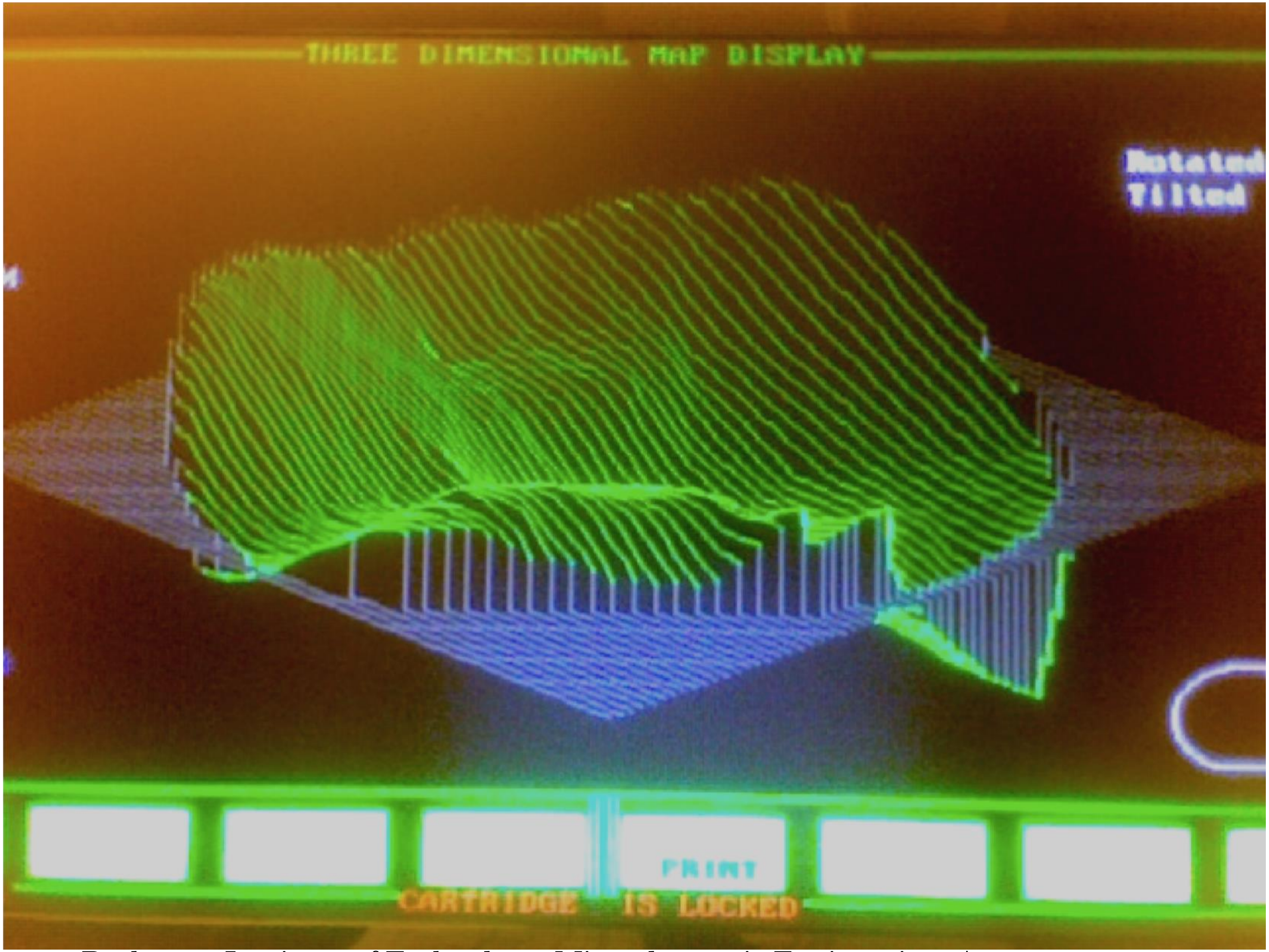
Wafer 1 Recipe 310 1000A 10L/min 1000C

- Mean: 1288.2
- Standard Deviation: 34.556 2.682%
- Minimum: 1222.4
- Maximum: 1388.5
- Range: 166.10
- #Sites/Good: 81/81


THREE DIMENSIONAL MAP DISPLAY
Rotated 0
Tilted 30
PRINT
CARTRIDGE IS LOCKED
acer

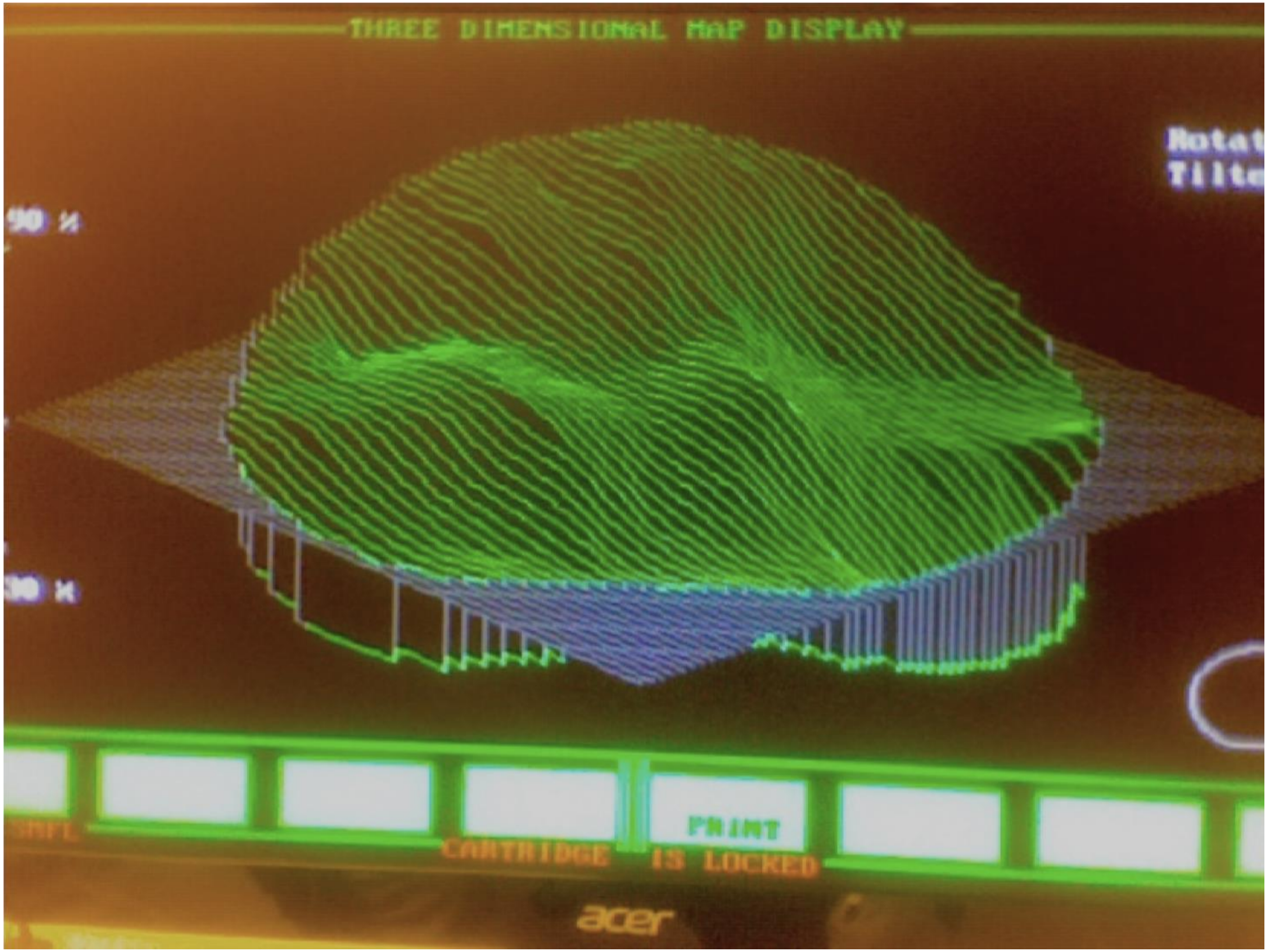
Wafer 2 Recipe 310 1000A 10L/min 1000C

- Mean: 1308.4
- Standard Deviation: 23.049   1.761%
- Minimum: 1261.6
- Maximum: 1352.6
- Range: 91.000
- #Sites/Good: 81/81


THREE DIMENSIONAL MAP DISPLAY
Rotated
Tilted
PRINT
CARTRIDGE IS LOCKED

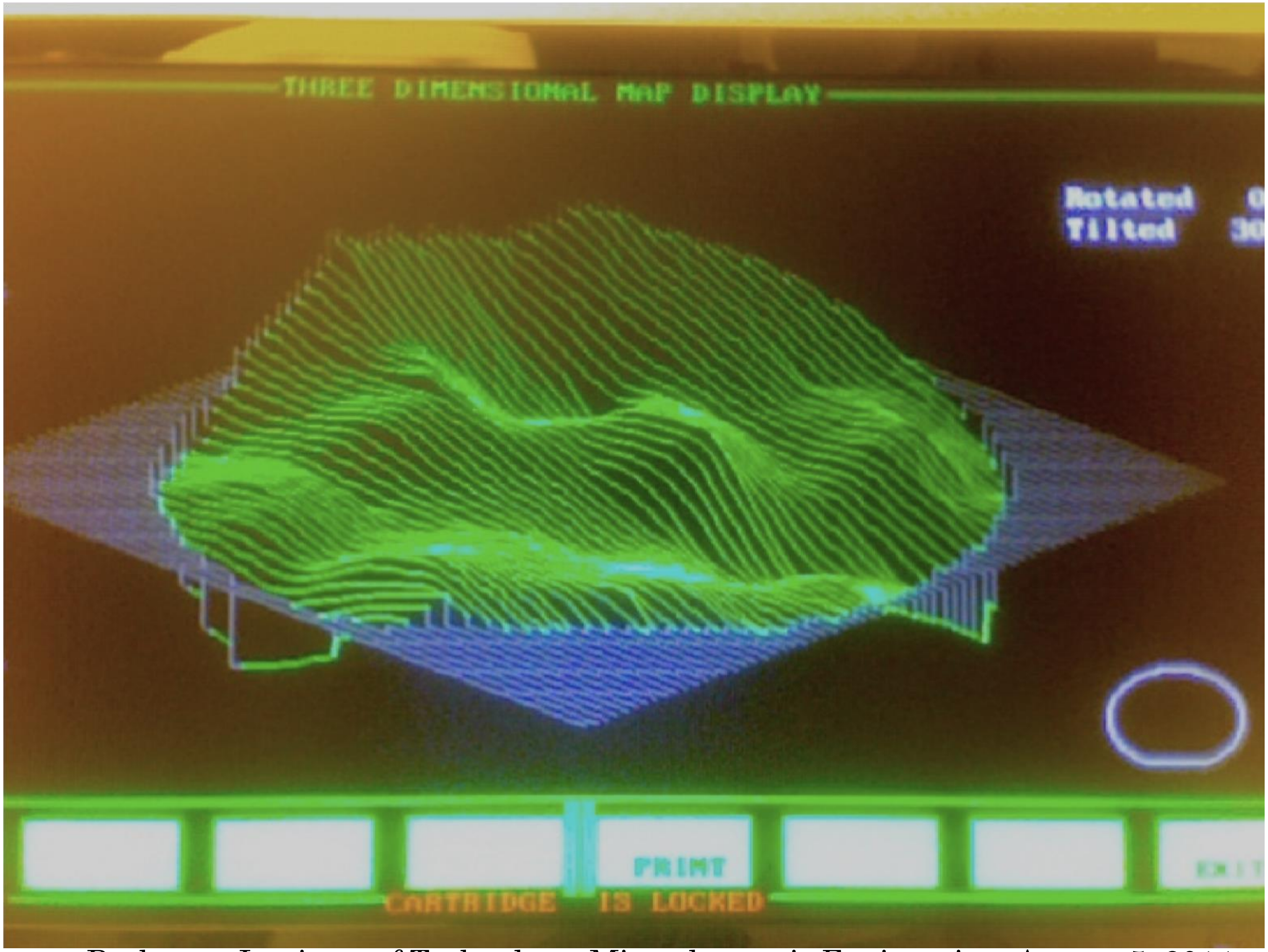
Wafer 1 Recipe 310 1000A 5L/min 1000C

- Mean: 1324.5
- Standard Deviation: 33.615   2.538%
- Minimum: 1267.6
- Maximum: 1402.6
- Range:135.10
- #Sites/Good: 81/81


THREE DIMENSIONAL MAP DISPLAY
PRINT
CARTRIDGE IS LOCKED

Wafer 2 Recipe 310 1000A 5L/min 1000C

- Mean: 1365.2
- Standard Deviation: 15.176   1.112%
- Minimum: 1327.0
- Maximum: 1409.6
- Range: 82.400
- #Sites/Good: 81/81


THREE DIMENSIONAL MAP DISPLAY
Rotated
Tilted
PRINT
CARTRIDGE IS LOCKED

Comparison and Results

	10L/min	5L/min	10L/min	5L/min
Mean	1288.2	1324.5	1308.4	1365.2
Standard Deviation	34.556 2.682%	33.615 2.538%	23.049 1.761%	15.176 1.112%
Min	1222.4	1267.6	1261.6	1327.0
Max	1388.5	1402.6	1352.6	1409.6
Range	166.10	135.10	91.000	82.400
#Sites/ Good	81/81	81/81	81/81	81/81

Calculations Ensuring Sufficient Quantity of Oxygen Gas Available

- Assume that 50 Wafers are present for a 500Angstrom oxide growth recipe, all wafers are coated uniformly, oxygen gas flows at 5L/min and is at STP upon entering Bruce Furnace.

$$Si + O_2 \rightarrow SiO_2$$

SiO_2 Density: 2.65g/cm^3 2650kg/m^3

SiO_2 Molar Mass: 60.08g/mol .06008kg/mol

Moles O_2 Needed for 500A SiO_2

- Volume SiO_2 Each Wafer
  - $V \approx \pi r^2 h$
    $\approx \pi(3in \times (1cm/0.3937in) \times (1m/100cm))^2(500A \times (10^{-10}m/1A))$
    $\approx 9.121 \times 10^{-10}\ m^3$
- Mass SiO_2 Each Wafer
  - Density = Mass/Volume   Mass = (Density)(Volume)
    $(2650kg/m^3)(9.121 \times 10^{-10}\ m^3)$
    $= 6.65 \times 10^{-7}kg$
- Total Moles SiO_2 (50 Wafers)
  - Moles = Mass/Molar Mass
    $(6.65 \times 10^{-7}kg\ /\ .06008kg/mol)(50\ wafers)$
    $= 5.535 \times 10^{-4}$ mol SiO_2
- Total Moles O_2 (50 Wafers)
  - $Si + O_2 \rightarrow SiO_2$
    5.535×10^{-4} mol SiO_2 (1 mol O_2 / 1 mol SiO_2)

5.535×10^{-4} mol O_2 necessary to grow 500A SiO_2

Moles O_2 Provided by 500A SiO_2 Recipe

- Liters of O_2 Used by Recipe
  - (47 minutes)(5L/min)

    235L
- Moles of O_2 Used by Recipe
  - (235L O_2)(1mol / 22.4L)

    10.49 mol O_2 provided

How Much Excess Oxygen?

- (10.49 mol provided) / (5.535 x 10^{-4} mol needed)

19,000 times the necessary amount

CONCLUSION

The data above shows that if the oxygen flow rate is reduced from 10L/min to 5L/min for a dry oxide growth process, it will not affect the thickness or uniformity of the oxide grown. Therefore, the oxygen usage can be reduced for dry oxide growth processes in recipes that use a 10L/min oxygen flow rate during the soak period. This could save approximately $2000 in cost every year.

References

- http://people.rit.edu/lffeee/
- http://people.rit.edu/lffeee/Bruce_Furnace.pdf
- Silicon VLSI Technology – Fundamentals, Practice and Modeling. Plummer, Deal and Griffin