Improving Manufacturing Performance

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TQM Challenge/Award

12-1-2012 Lec_tqm.ppt

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OUTLINE

Introduction

Tools – TQM, CIM, SPC, 6σ

Six Sigma Concepts

Key Parameters

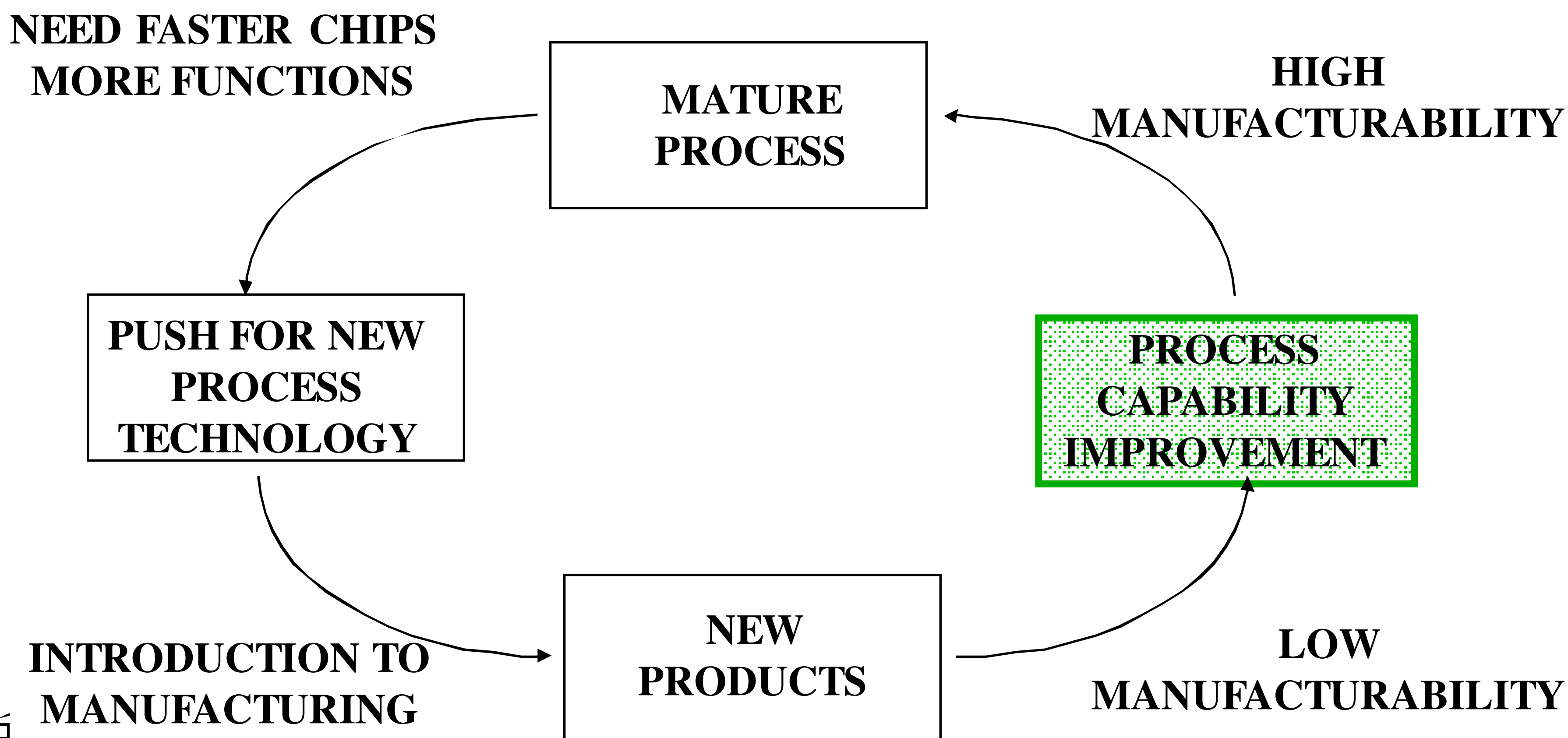
Baseline Evaluation

Continuous Improvement

Examples: LPCVD Nitride, Oxide Growth

Results, Future Work & Conclusion

EVOLUTION OF MANUFACTURABILITY



TOOLS FOR IMPROVING MANUFACTURING

TQM – Total Quality Management

CIM – Computer Integrated Manufacturing

SPC – Statistical Process Control

6σ - Six Sigma Process Capability Analysis

TQM - TOTAL QUALITY MANAGEMENT

TQM is a way to run a company that focuses on continually improving how you do things and what you do in order to satisfy all **customer needs**. TQM combines management methods and **statistical tools** in one package and gives all members of an organization a common **goal**.

Quality is defined as "***conformance to customer requirements***", lack of defects and the companies own standards of final product.

TQM sets up **rules of behavior** and **goals of conduct** for the employees, giving them a sense of **mission** as they strive to achieve their **vision**.

You work together as a **team** to solve problems.

CIM - COMPUTER INTEGRATED MANUFACTURING

CIM - Concept in which computer software and hardware is integrated throughout a manufacturing facility to provide integration among functions such as engineering and research, production planning, plant operations, shipping, receiving, business management, marketing, everything (including CAD and CAM)

CAD - Computer Aided Design, software and hardware tools needed to design the product including, circuit simulators, layout editors, process simulators, and more,

CAM - Computer Aided Manufacturing - software and hardware tools needed for work in process tracking, statistical process control, facilities monitoring, robotics, artificial intelligence, expert systems, and more.

SPC - STATISTICAL PROCESS CONTROL

CIM system integrated with SPC software

- operators review SPC charts before processing (TQM)
- process adjustments can be made if necessary (TQM/CIM)

SPC alarms and actions if process violates SPC rules:

- send notice to specific users (TQM/CIM)
- prevent further processing of job, operation or tool (CIM)

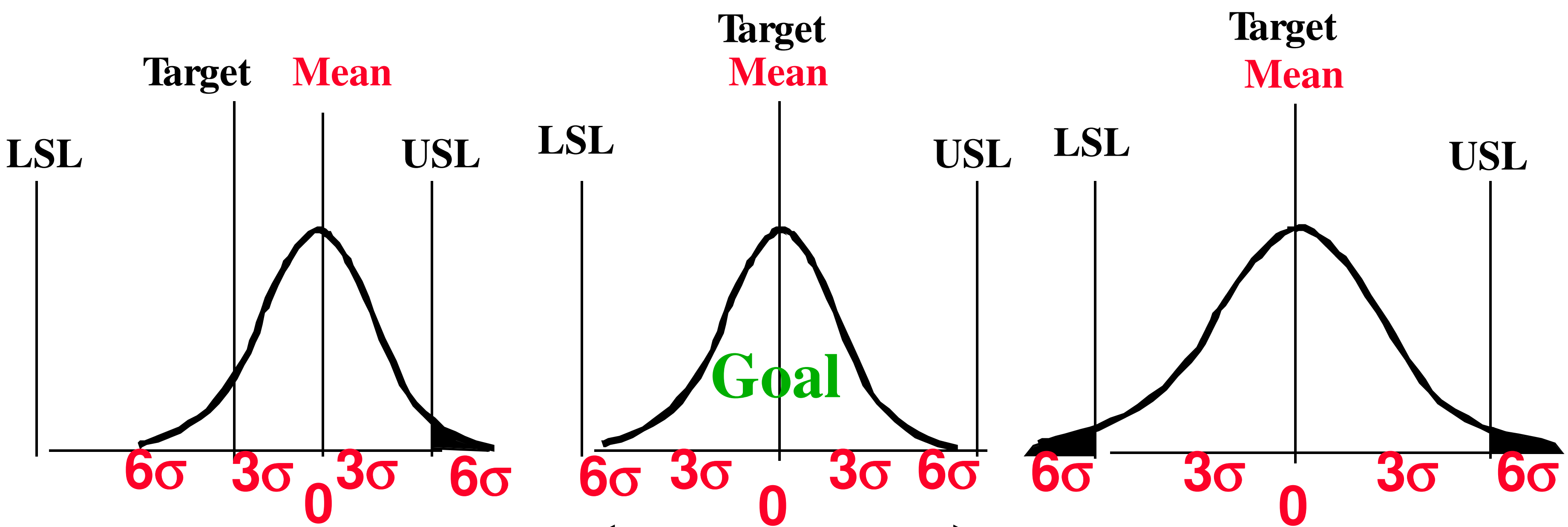
Corrective Actions

- Teams solve problems (TQM)

List of actions if SPC rules are violated

- OCAP, Out of Control Action Plans (SPC)

SIX SIGMA CONCEPTS

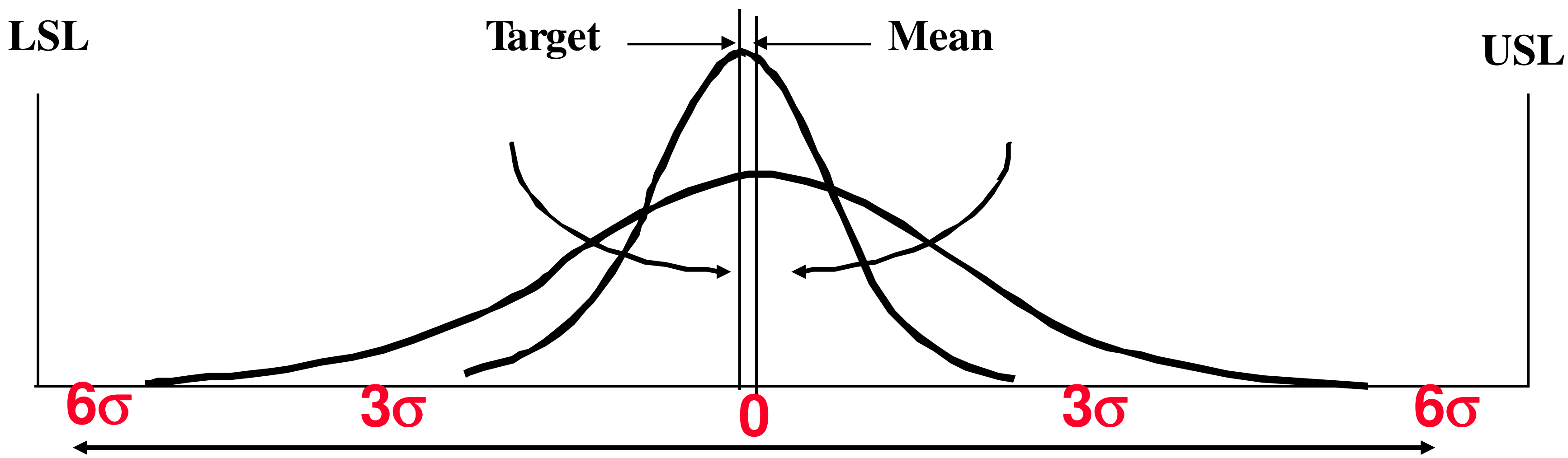


Process Mean off target

Process Variation within specification limits

Process Variation larger than specification limits

SIX-SIGMA CONCEPTS



Reduce Variation

locate 6σ points within USL and LSL

Position Mean at Target

Goal of Cp=2.0, k=0, Cpk=2.0

to give less than 3.4 ppm defects

DEFINITION OF TERMS

§ **Process Potential**
Goal is Cp=2

$$Cp = \frac{(USL - LSL)}{6\,\sigma}$$

§ **Centering Factor**
Goal is K =0

$$K = \frac{[Tget - \mu]}{(USL - LSL)/2}$$

§ **Process Capability**
Goal is Cpk = 2

$$Cpk = \text{Smallest of: } \left\{ \frac{\mu - LSL}{3\,\sigma} ; \frac{USL - \mu}{3\,\sigma} \right\}$$

Sigma when calculated from multiple samples of multiple points and only the average, sigma and number of points is stored for each sample. Then the overall mean and sigma is calculated as shown:

$$xbar = \frac{\Sigma\, xi}{n} \qquad Mean = \frac{\Sigma\, xbar}{A}$$

Example: Say we measure oxide thickness (xi) at 5 sites (n=5) on a wafer after oxide growth and average them to get a value (xbar) to put into our data base, then n = 5, xbar = sum of the five data points divided by 5. If we look at the data for 10 lots (A=10) then the mean is the sum of the 10 average values (xbar) divided by 10. We also save the standard deviation (σ) of the 5 data points in the data base and the combined overall standard deviation is Sigma shown below.

$$\sigma = \sqrt{\frac{\Sigma\,(xi-xbar)^2}{(n-1)}} \qquad Sigma = \sqrt{\frac{\Sigma\,[(n-1)\sigma i^2 + n\, xbar^2] - (An)\mu}{(An) - 1}}$$

EXAMPLE:

Oxide Thickness												
Lot No.	1	2	3	4	5	6	7	8	9	10		
	4920	4850	5120	5120	5000	5200	4800	4700	5010	5100		
	4875	4750	5150	5089	4930	5128	4750	4992	5080	5109		
	4865	4680	5210	5142	5046	5089	4910	4708	4996	5080		
	4789	4780	5190	5156	5075	5078	4853	4786	4980	5088		
	4965	4652	5175	5048	4959	5165	4700	5650	5024	5187		
Mean	4882.8	4742.4	5169	5111	5002	5132	4802.6	4967.2	5018	5112.8	Recorded in	
stdev	65.79666	79.23888	35.07136	43.35897	59.79548	51.22011	82.72726	399.4511	38.31449	42.93833	data base	
Target	5000		Mean of means =		4993.98		mean of all data =		4993.98			
USL	5500		stdev formula =		187.0388		stdev all data =		187.0388			
LSL	4500											
CP=	0.89108		K=	0.01204		Cpk = (μ - LSL)/3σ		0.880352				
									smallest of these two			
						Cpk = (USL - μ)/3σ		0.901809				

RIT'S PATHWAY TO 6 SIGMA

Define Key Parameters

Final System Performance, Manufacturing, Reliability

Baseline

Current Process Capability, Mean, Sigma, CP, K, CPK

Process Capability Improvement

Implement Actions, Process Adjustments, Hardware Changes, Process Alternatives

Monitor Process Performance

Real Time SPC, Limits and Corrective Actions

KEY PARAMETERS

Final System Performance Parameters

- Gain of an Amplifier
- Frequency Response of a Filter
- Noise Margin of a Digital Gate

Manufacturing Yield or Line Control Parameters

- Kooi Oxide Thickness
- Gate Oxide Thickness
- Metal Thickness
- Via Slope (Reliability)
- Room Humidity
- DI Water Resistivity

Note: in industry it is typical to keep track of ~300 key parameters

RIT'S KEY MANUFACTURING PARAMETERS

- Masking Oxide Thickness
- Pad Oxide Thickness
- Field Oxide Thickness
- Kooi Oxide Thickness
- Gate Oxide Thickness
- X and Y overlay level 2,3,4,5, etc
- Metal Thickness
- Nitride Thickness
- Poly Thickness

RIT'S KEY PARAMETERS AT TEST

- Sheet Resistance PMOS D/S
- Sheet Resistance NMOS D/S
- Sheet Resistance Poly
- Sheet Resistance Well
- Sheet Resistance Metal
- Contact Resistance M/P, M/N+,M/P+
- MOSFET Vt, Gm, Isub min, λ
- Field Vt

RIT'S KEY SYSTEM PERFORMANCE PARAMETERS

- Measured Gain for G = 3 Inverter
- Inverter Noise Margins, Imax
- Ring Oscillator Gate Delay, td
- Op Amp Open Loop Gain
- Op Amp Input Offset Voltage

REVIEW OF TARGET, USL AND LSL

The target, USL and LSL for each key parameter is reviewed by a team of engineers using appropriate simulation tools, calculations and experience.

For example: the pad oxide target might be selected to be 1/3 of the nitride thickness for relief of stress in the nitride film (experience). The lower spec is determined by the ability for the pad oxide to act as an etch stop (experience) during nitride plasma etch leaving enough oxide to act as a screening oxide (simulation) for the subsequent ion implant. The upper spec limit is determined by the acceptable amounts of ion implant masking (simulation) and LOCOS birds beak (simulation). All of these are difficult to determine precisely, compromise and margin of error are considered in determining the values for target, USL and LSL.

KEY PARAMETER TARGETS, USL, LSL

Name	Units	Target	LSL	USL
Masking Oxide	Å	5000	4500	5500
Pad Oxide Thickness	Å	500	400	600
Nitride Thickness	Å	1500	1000	2000
Field Ox Thickness	Å	10000	9000	11000
Photo x-overlay	µm	0	-2	2
Photo y-overlay	µm	0	-2	2
Kooi Ox Thickness	Å	1000	900	1100
Gate Ox Thickness	Å	500	450	550
Poly Thickness	Å	6000	5000	7000
Poly Sheet Rho	ohms	25	10	50
LTO Thickness	Å	4000	3000	5000
Metal Thickness	Å	7500	5000	10000
Rho n+	ohms	25	10	50
Rho p+	ohms	25	10	50
Rho metal	ohms	0.1	0.05	0.5
Gc met-N+	mhos/um2	1	0.1	10
Nmos Vt	Volts	1	0.5	1.5
Nmos Sub Vt Slope	mV/dec	100	75	125
Nmos Imin	nAmps	1	0.01	100
Pmos Vt (magnitude)	Volts	1	0.5	1.5
Pmos Sub Vt Slope	mV/dec	100	75	125
Pmos Imin	nAmps	1	0.01	100
Vinvert	Volts	2.5	2	3

BASELINE EVALUATION, DATA ANALYSIS DETAILS

A data base query is made and the most recent data is used to calculate Cp, K and Cpk. The data is plotted and compared to a theoretical "6sigma" plot using the following equation.

$$\text{"6sigma Distribution"} = \frac{\mathrm{Exp}(-(x-\mu)^2/2\sigma^2)}{\sigma\,(2\,\Pi)^{0.5}}$$

where μ (the mean) is set to the target value and σ (the standard deviation) is set to USL-LSL/12.

(see /tools/Cpk.xls)

QUERY MESA DATA BASE

```
                              Work with Queries

Library . . . . . . . . .   QGPL          Name, *LIBL, F4 for list
Subset  . . . . . . . . .   __________    Name, generic*
Position to . . . . . . .   __________    Starting characters

Type options (and Query), press Enter.
  1=Create   2=Change   3=Copy   4=Delete   5=Display   6=Print
  8=Run in batch   9=Run
Opt  Query           Text                                            Changed
 _   __________
 2   SPC6SC_PAD      PAD OXIDE QUERY FOR SPC - DR. FULLER            09/09/07
 _   SPC6SC_POL      POLYSILICON THICKNESS FOR SPC CHARTS-DR. FUL    12/04/07
 _   SPC6SC_PRS      P+ DRAIN/SOURCE SHEET RESISTANCE FOR SPC-DR.    03/27/02
 _   SPC6SC_WO       WELL OXIDE FOR SPC CHARTS-DR. FULLER            09/07/07
 _   SPC6SC_WRS      WELL SHEET RESISTANCE FOR SPC-DR. FULLER        09/07/07
 _   SPC6SC_2CD      SPC 2 UM CD - DR. FULLER                        04/22/02
 _   SPC6SC_350      Recipe350-WellOxide-DR. FULLER                  06/07/05
 _   SPC6SCPORS      Polysilicon Sheet Resistance for SPC-Dr. Ful    09/07/07
 _   STATUS          FACTORY LOT FORWARD ADVANCEMENT - DR. FULLER    08/17/00
                                                                       More...
F3=Exit        F4=Prompt           F5=Refresh       F11=Display names only
F12=Cancel     F19=Next group
File SC6PAD in QGPL was replaced.                                            +
MA     a               MW                                             13/003
```

F5 - REPORT

Display Report

Report width . . . . . : 68

Position to line . . . . . ______ Shift to column . . . . . . ______

Line ....+....1....+....2....+....3....+....4....+....5....+....6....+...

Line	DATE	Lot number	Thickness	Soak Time	Soak Temperature	Furnace ID
000016	20070913	F070208	513	50	1,000	
000017	20070919	F070910	519	50	1,000	
000018	20070920	F070212	516	53	1,000	
000019	20070926	F070924	507	54	1,000	
000020	20070929	F070420	532	40	1,000	
000021	20071002	F071001	540	54	1,000	
000022	20071016	F070924	554	50	1,000	
000023	20071024	F070903	492	54	1,000	
000024	20071204	F070910	518	54	1,000	
000025	20071210	F071203	554	54	1,000	
000026	20071213	F071206	510	50	1,000	
000027	20071217	F071001	516	50	1,000	

****** ******** End of report ********

Bottom

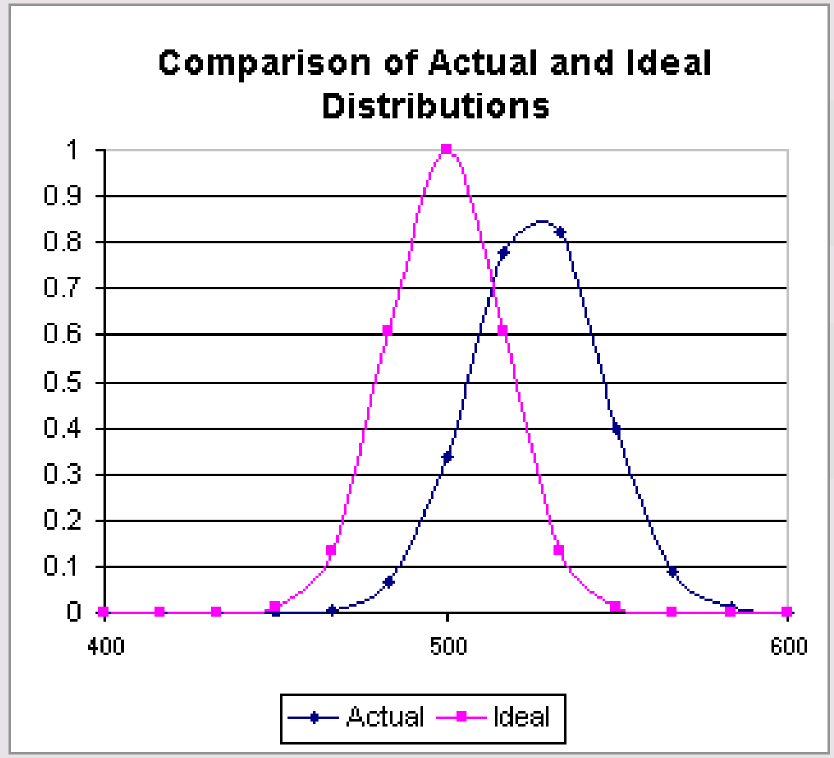
F3=Exit F12=Cancel F19=Left F20=Right F21=Split

MA a MW A 03/032

CPK.XLS SPREAD SHEET FOR DATA ANALYSIS

10	VARIABLES							
11	Target	500		Cp =	1.772	Goal is Cp = 2		
12	USL	600		K =	-0.262	Goal is K = 0		
13	LSL	400		Cpk =	2.237	Goal is Cpk = 2		
14				or Cpk =	1.308	smallest		
15	Data	538						
16		553		Cp = (USL_LSL)/6 sigma				
17		531		K = (target - mean)/(USL-LSL)/2				
18		519		Cpk = smallest of :{(mean - LSL)/3sigma or				
19		516			(USL - mean)/3sigma}			
20		507		mean	526.20			
21		532		sigma	18.81			
22		540	σ=USL-LSL/12		16.67	Cp=2.0		
23		554						
24		492						
25		518	Value	Actual	Ideal		Target	500
26		554					USL	600
27		510	400	1E-10	1.515E-08		LSL	500
28		516	416.67	4E-08	3.713E-06			
29		513	433.33	4E-06	0.0003347			
30			450	0.0002	0.0110939			
31			466.67	0.0059	0.1352535			
32			483.33	0.0659	0.6064391			
33			500	0.3357	1	0.02398		
34			516.67	0.7793	0.6064391			
35			533.33	0.8246	0.1352535			
36			550	0.3978	0.0110939			
37			566.67	0.0875	0.0003347			
38			583.33	0.0088	3.713E-06			
39			600	0.0004	1.515E-08			

Pad Oxide Thickness



Ideal is shown with sigma equal to (USL-LSL)/12 which corresponds to Cpk=2.0

GATE, FIELD, WELL, KOOI OXIDE

Field Xox

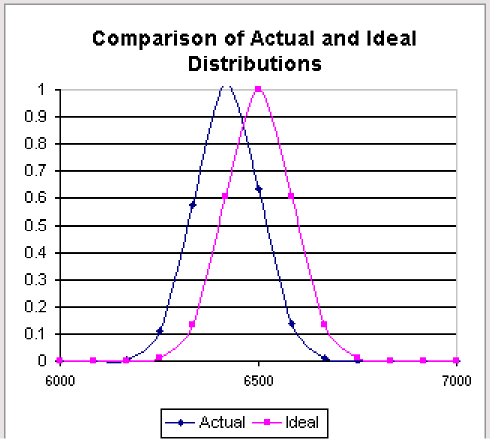
Field Oxide Thickness

Cp =	2.048	Goal is Cp = 2
K =	0.158	Goal is K = 0
Cpk =	1.723	Goal is Cpk = 2
or Cpk =	2.372	smallest

Cp = (USL_LSL)/6 sigma
K = (target - mean)/(USL-LSL)/2
Cpk = smallest of :{(mean - LSL)/3sigma or (USL - mean)/3sigma}

mean	6420.86	
sigma	81.40	
σ=USL-LSL/12	83.33	Cp=2.0

Value	Actual	Ideal			
				Target	6500
				USL	7000
6000	2E-06	1.515E-08		LSL	6500
6083.3	0.0002	3.713E-06			
6166.7	0.0078	0.0003347			
6250	0.113	0.0110939			
6333.3	0.5742	0.1352535			
6416.7	1.0224	0.6064391			
6500	0.6381	1	0.0048		
6583.3	0.1396	0.6064391			



Well Xox

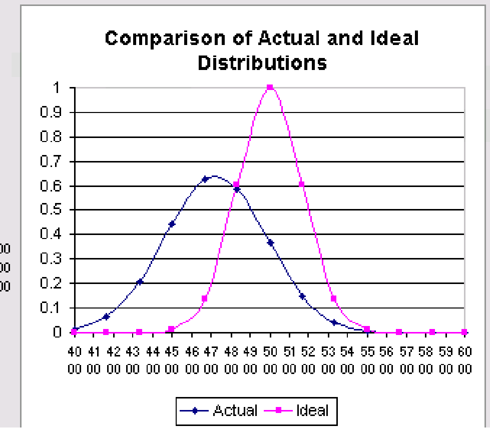
Well Oxide Thickness

Cp =	1.283	Goal is Cp = 2
K =	0.276	Goal is K = 0
Cpk =	0.929	Goal is Cpk = 2
or Cpk =	1.638	smallest

Cp = (USL_LSL)/6 sigma
K = (target - mean)/(USL-LSL)/2
Cpk = smallest of :{(mean - LSL)/3sigma or (USL - mean)/3sigma}

mean	4723.67	
sigma	259.78	
σ=USL-LSL/12	166.67	Cp=2.0

Value	Actual	Ideal			
				Target	5000
				USL	6000
4000	0.0132	1.515E-08		LSL	5000
4166.7	0.0644	3.713E-06			
4333.3	0.2074	0.0003347			
4500	0.4428	0.0110939			
4666.7	0.6263	0.1352535			
4833.3	0.5869	0.6064391			
5000	0.3643	1	0.0024		
5166.7	0.1498	0.6064391			



Gate Xox

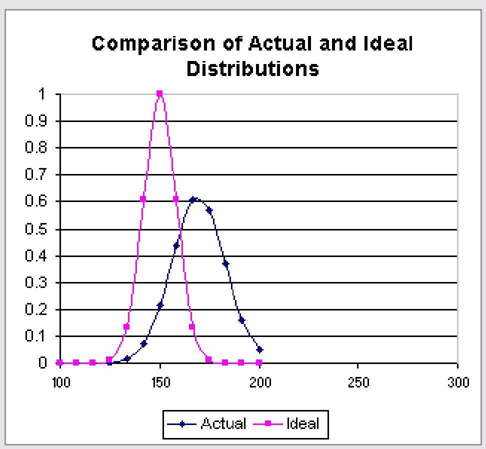
Gate Oxide Thickness

Cp =	1.240	Goal is Cp = 2
K =	-0.392	Goal is K = 0
Cpk =	1.725	Goal is Cpk = 2
or Cpk =	0.754	smallest

Cp = (USL_LSL)/6 sigma
K = (target - mean)/(USL-LSL)/2
Cpk = smallest of :{(mean - LSL)/3sigma or (USL - mean)/3sigma}

mean	169.60	
sigma	13.45	
σ=USL-LSL/12	8.33	Cp=2.0

Value	Actual	Ideal			
				Target	150
				USL	200
100	9E-07	1.515E-08		LSL	150
108.33	2E-05	3.713E-06			
116.67	0.0003	0.0003347			
125	0.0025	0.0110939			
133.33	0.0163	0.1352535			
141.67	0.0716	0.6064391			
150	0.2141	1	0.04796		
158.33	0.4362	0.6064391			



Kooi Xox

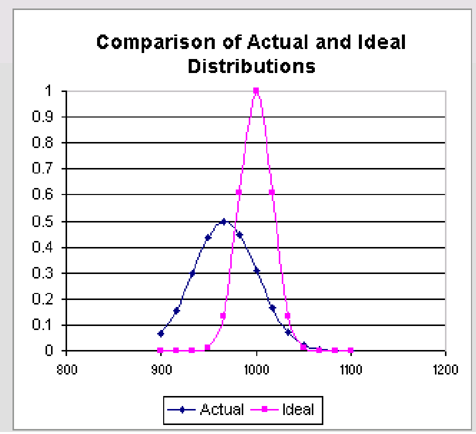
Kooi Oxide Thickness

Cp =	0.998	Goal is Cp = 2
K =	0.326	Goal is K = 0
Cpk =	0.673	Goal is Cpk = 2
or Cpk =	1.322	smallest

Cp = (USL_LSL)/6 sigma
K = (target - mean)/(USL-LSL)/2
Cpk = smallest of :{(mean - LSL)/3sigma or (USL - mean)/3sigma}

mean	967.44	
sigma	33.41	
σ=USL-LSL/12	16.67	Cp=2.0

Value	Actual	Ideal			
				Target	1000
				USL	1100
900	0.065	1.515E-08		LSL	1000
916.67	0.1571	3.713E-06			
933.33	0.2962	0.0003347			
950	0.4353	0.0110939			
966.67	0.4987	0.1352535			
983.33	0.4455	0.6064391			
1000	0.3103	1	0.02398		
1016.7	0.1685	0.6064391			



PAD OXIDE, NITRIDE, POLY, METAL THICKNESS

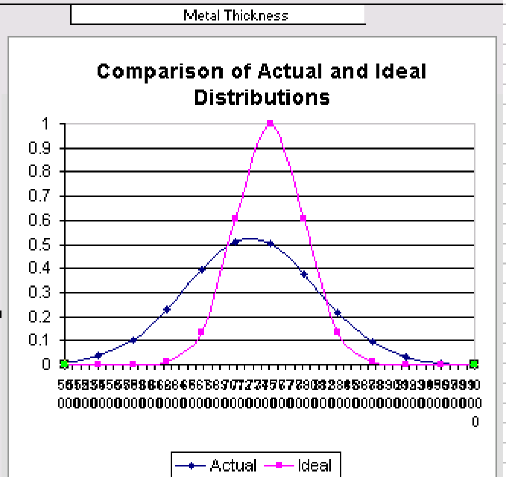
Metal Thickness

Cp =	1.046	Goal is Cp = 2
K =	0.093	Goal is K = 0
Cpk =	0.949	Goal is Cpk = 2
or Cpk =	1.143	smallest

Cp = (USL_LSL)/6 sigma
K = (target - mean)/(USL-LSL)/2
Cpk = smallest of :{(mean - LSL)/3sigma or (USL - mean)/3sigma}

mean	7268.00	
sigma	796.93	
σ=USL-LSL/12	416.67	Cp=2.0

Value	Actual	Ideal			
				Target	7500
				USL	10000
5000	0.0091	1.515E-08		LSL	7500
5416.7	0.0352	3.713E-06			
5833.3	0.1034	0.0003347			
6250	0.2312	0.0110939			
6666.7	0.3933	0.1352535			
7083.3	0.509	0.6064391			
7500	0.5011	1	0.00096		
7916.7	0.3754	0.6064391			



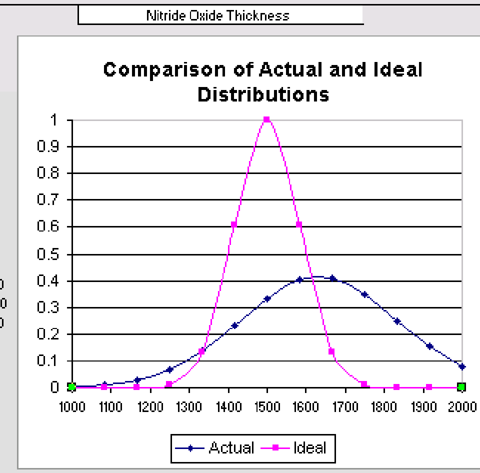
Nitride Thickness

Cp =	0.829	Goal is Cp = 2
K =	-0.264	Goal is K = 0
Cpk =	1.047	Goal is Cpk = 2
or Cpk =	0.610	smallest

Cp = (USL_LSL)/6 sigma
K = (target - mean)/(USL-LSL)/2
Cpk = smallest of :{(mean - LSL)/3sigma or (USL - mean)/3sigma}

mean	1632.08	
sigma	201.15	
σ=USL-LSL/12	83.33	Cp=2.0

Value	Actual	Ideal			
				Target	1500
				USL	2000
1000	0.003	1.515E-08		LSL	1500
1083.3	0.01	3.713E-06			
1166.7	0.0285	0.0003347			
1250	0.0682	0.0110939			
1333.3	0.1375	0.1352535			
1416.7	0.2334	0.6064391			
1500	0.3339	1	0.0048		
1583.3	0.4023	0.6064391			



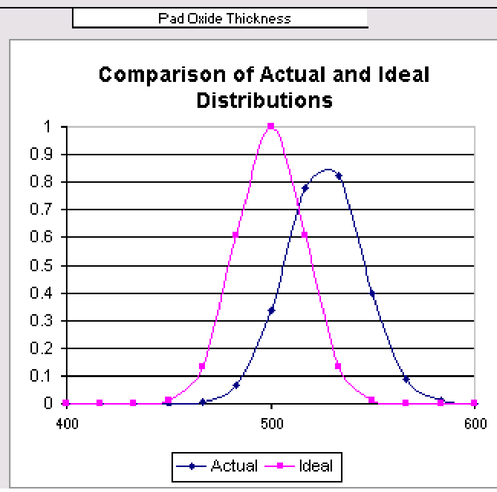
Pad Xox

Cp =	1.772	Goal is Cp = 2
K =	-0.262	Goal is K = 0
Cpk =	2.237	Goal is Cpk = 2
or Cpk =	1.308	smallest

Cp = (USL_LSL)/6 sigma
K = (target - mean)/(USL-LSL)/2
Cpk = smallest of :{(mean - LSL)/3sigma or (USL - mean)/3sigma}

mean	526.20	
sigma	18.81	
σ=USL-LSL/12	16.67	Cp=2.0

Value	Actual	Ideal			
				Target	500
				USL	600
400	1E-10	1.515E-08		LSL	500
416.67	4E-08	3.713E-06			
433.33	4E-06	0.0003347			
450	0.0002	0.0110939			
466.67	0.0059	0.1352535			
483.33	0.0659	0.6064391			
500	0.3357	1	0.02398		
516.67	0.7793	0.6064391			



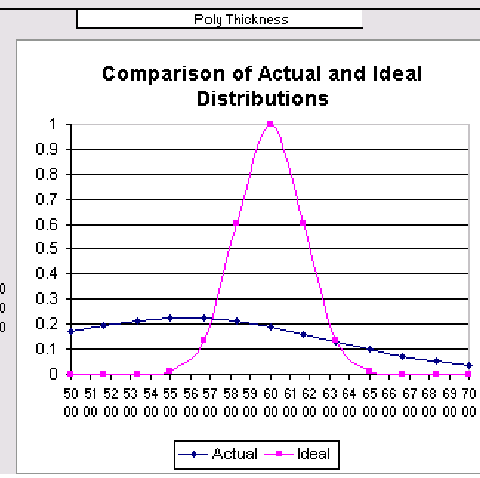
Poly Thickness

Cp =	0.451	Goal is Cp = 2
K =	0.441	Goal is K = 0
Cpk =	0.252	Goal is Cpk = 2
or Cpk =	0.650	smallest

Cp = (USL_LSL)/6 sigma
K = (target - mean)/(USL-LSL)/2
Cpk = smallest of :{(mean - LSL)/3sigma or (USL - mean)/3sigma}

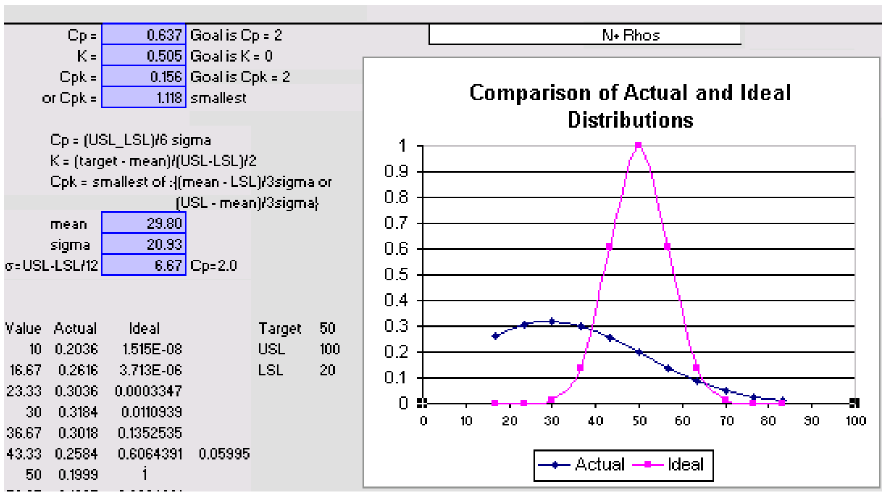
mean	5559.20	
sigma	738.62	
σ=USL-LSL/12	166.67	Cp=2.0

Value	Actual	Ideal			
				Target	6000
				USL	7000
5000	0.1694	1.515E-08		LSL	6000
5166.7	0.1959	3.713E-06			
5333.3	0.2153	0.0003347			
5500	0.2249	0.0110939			
5666.7	0.2233	0.1352535			
5833.3	0.2106	0.6064391			
6000	0.1888	1	0.0024		
6166.7	0.1609	0.6064391			

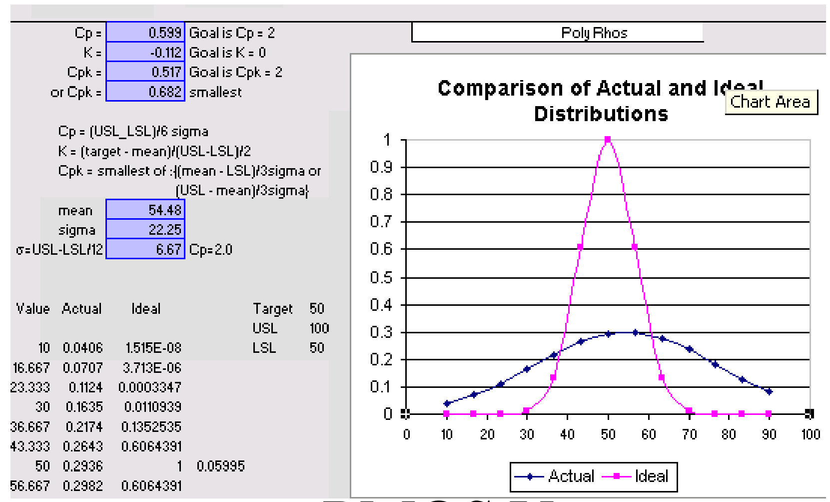


NMOS AND PMOS VT, N+ AND P+ RHOS

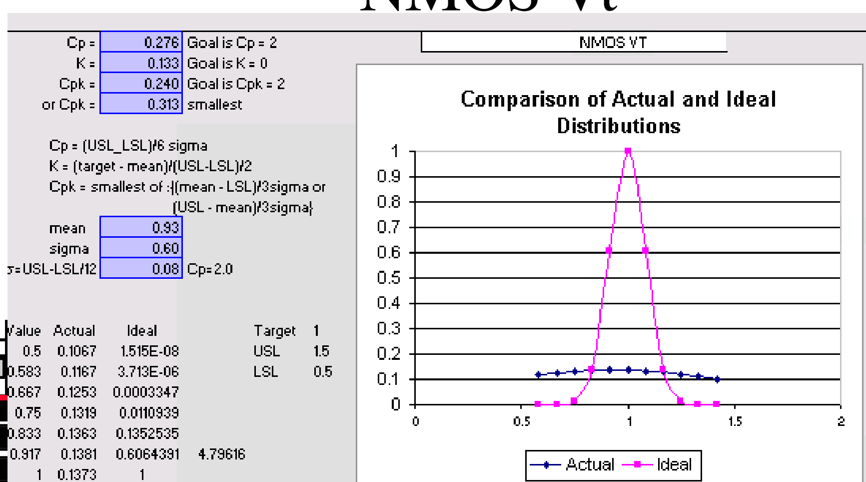
N+ D/S



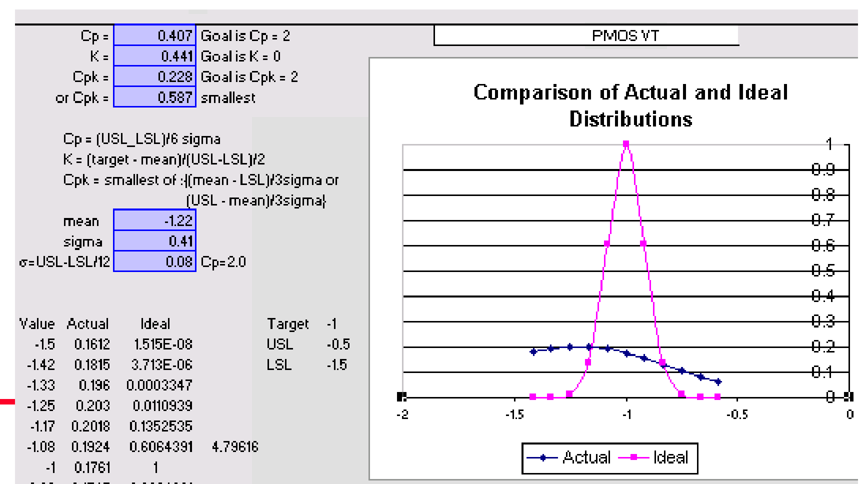
Poly Rhos



NMOS Vt



PMOS Vt



BASELINE EVALUATION JANUARY 7, 2008

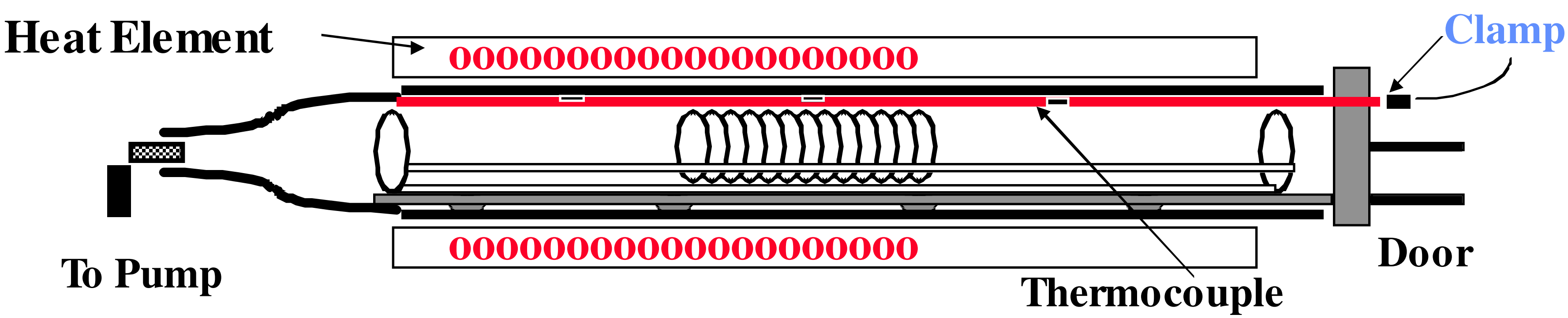
Parameter	Target	USL	LSL	CP	K	CPK
Pad Oxide Thickness	500Å	600Å	400Å	1.772	-0.262	1.308
Well Oxide	5000	5500	4500	1.283	0.276	0.929
Kooi Oxide	1000	1100	900	0.998	0.326	0.673
Field Oxide	6500	8000	5000	2.048	0.158	1.723
Gate Oxide	150	200	100	1.24	-0.392	0.754
Nitride Thickness	1500	2000	1000	0.829	-0.264	0.610
2^{nd} Nitride Thickness	3500	4000	3000	0.608	-0.674	0.198
Poly Thickness	6000	7000	5000	0.451	0.441	0.252
Al Thickness	7500	10000	5000	1.046	0.093	0.949
Poly Rhos	50	100	20	0.599	-0.112	0.517

More left to the students for homework

PROCESS CAPABILITY IMPROVEMENT

- Concentrate on Parameters Which are Least Capable
- Review Specification Limits and Target
- Develop an Action Plan Which Will Improve the Process and Raise CPK
  - Improved Reaction to SPC
  - Hardware Changes
  - New Equipment
  - Improve Process Latitude
- Assign a Person Responsible for Implementing the Action Plan

LPCVD EXAMPLE



LPCVD Nitride requires a temperature ramp from 800 C at the door to 820 C at the pump

Problem:

The position of the thermocouple is critical and was variable

Action:

A clamp was added to ensure repeatable placement of the thermocouple

Result: Cpk Improved from 0.33 to 1.35 in three months

OXIDE GROWTH EXAMPLE

Change the furnace recipe so that RIT's variable ramp down times do not affect the oxide thickness. Start soak time at 10 °C below soak temperature*

BEFORE:
Push at 900 C at 8 in/min in N2
Ramp up 900 C to 1100 C in Dry O2
Soak at 1100 C in Dry O2 Time 1
Ramp down from 1100 to 1000 in Dry O2
Pull at 1000 C at 8 in/min in N2

AFTER:
Push at 900 C at 8 in/min in N2
Ramp up 900 C to 1100 C in Dry O2
Soak at 1100 C in Dry O2 Time 2*
Ramp down from 1100 to 1000 in N2
Pull at 1000 C at 8 in/min in N2

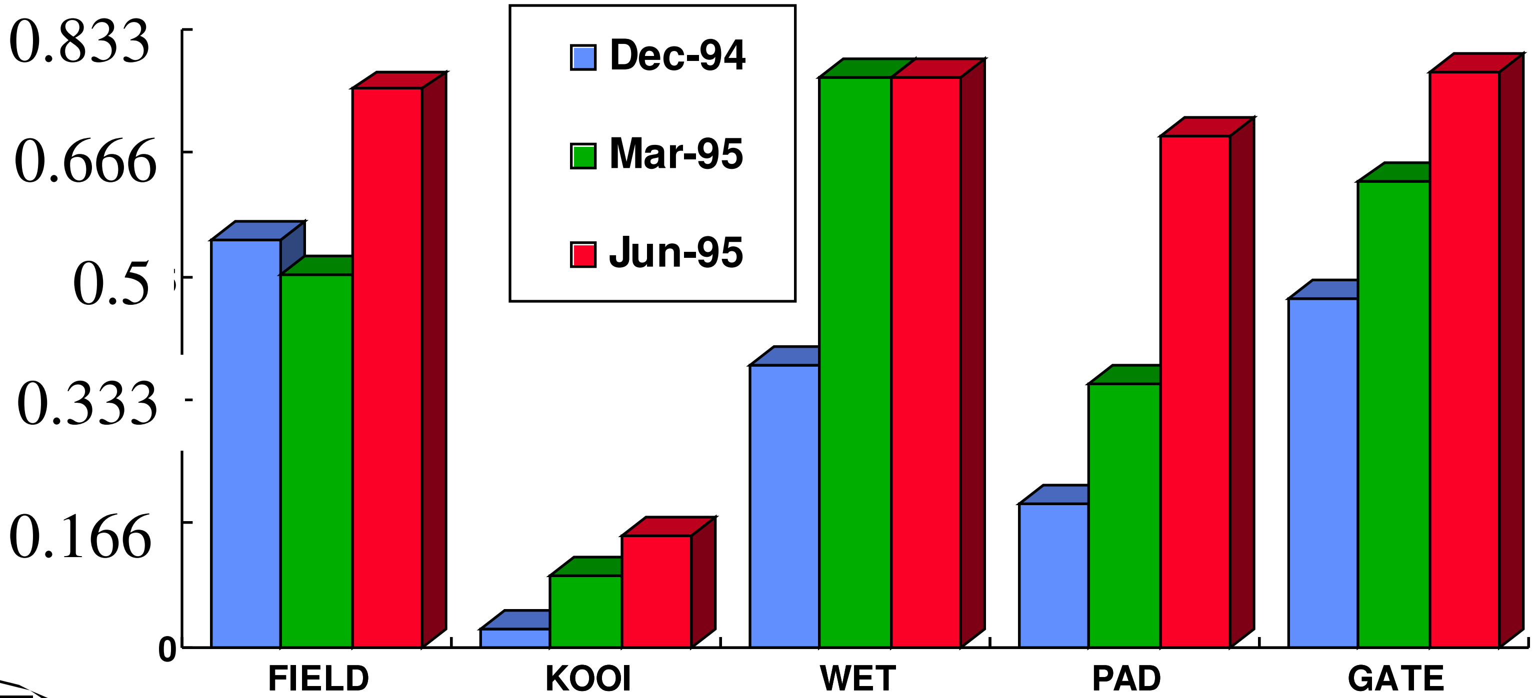
*** Start soak time at 10 °C below desired soak temperature**

MEASUREMENT OF IMPROVEMENT

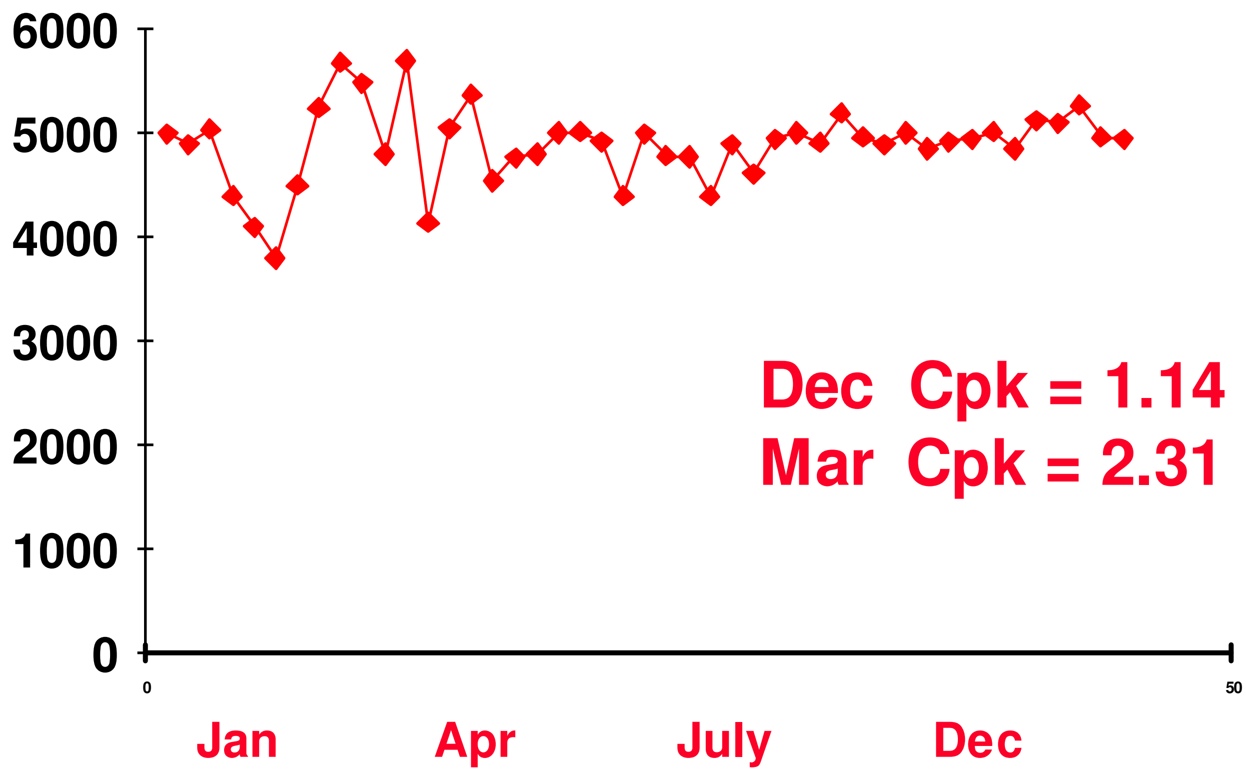
Process Parameter	Dec-94	Mar-95	Jun-95
	Cpk	Cpk	Cpk
Masking Oxide Thick	0.38	0.77	0.77
Drive Oxide Thickness	0.84	0.73	0.72
Field Oxide Thickness	0.55	0.50	0.75
Gate Oxide Thickness	0.47	0.63	0.78
Kooi Oxide Thickness	0.02	0.10	0.15
Pad Oxide Thickness	0.19	0.36	0.69
Metal Thickness	0.10	0.33	0.20
N+ DS Rhos	0.08	0.05	0.05
P+ DS Rhos	0.43	0.16	0.05
Poly Thickness	0.31	0.75	0.67
Poly Rhos	0.51	0.51	0.51
Well Rhos	0.34	0.73	0.73

IMPROVEMENTS IN OXIDE GROWTH

Cpk for Several Oxide Processes at 3 month increments



5000 Å OXIDE GROWTH



MONITOR PROCESS PERFORMANCE WITH SPC

Mesa data base queries are run that put the results into a data file.

Using the data in the data file, SPC charts are created by "NWA Quality Analyst Software" or other appropriate software.

Tool operators are taught how to evaluate the SPC charts for out of control criteria and what to do if the data shows an out of control condition (OCAP).

SPC alarms can automatically send notice to specific users and prevent further processing of job, operation or tool.

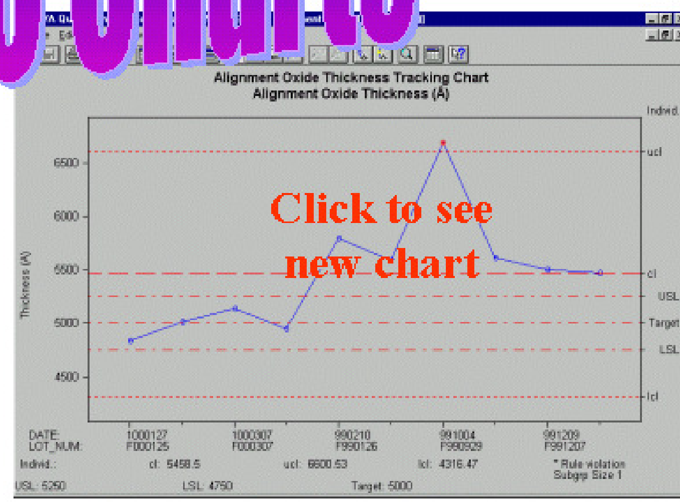
Teams evaluate and correct the problem.

SPC MAIN MENU SEEN IN MESA

fuller.microe.rit.edu

EXIT

Pad Oxide SPC Charts



Process Out of Control If:

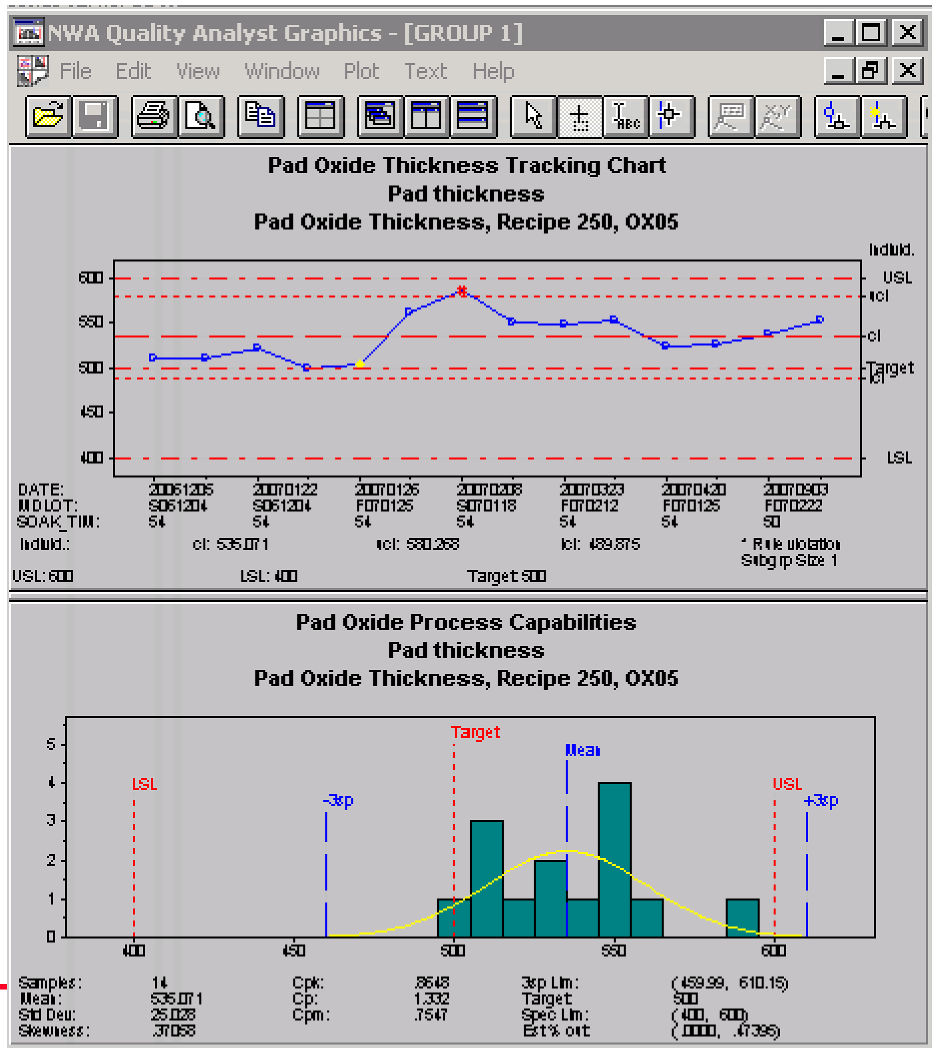
- any point outside the spec limits (i.e. a single point above or below 3 sigma)
- a run of 6 or more points increasing or decreasing
- a run of 5 or more points above/below the target
- 2 of 3 points above/below 2 sigma

If process is out of control initiate the out of control action plan

Click to see Action Plan

More Questions? Click Me

NWA QUALITY ANALYST, SPC CHART



Pad Oxide
Target 500Å
USL 600Å
LSL 400Å
Mean 535Å
Std Dev 25Å
Cpk 0.8648
Cp 1.332

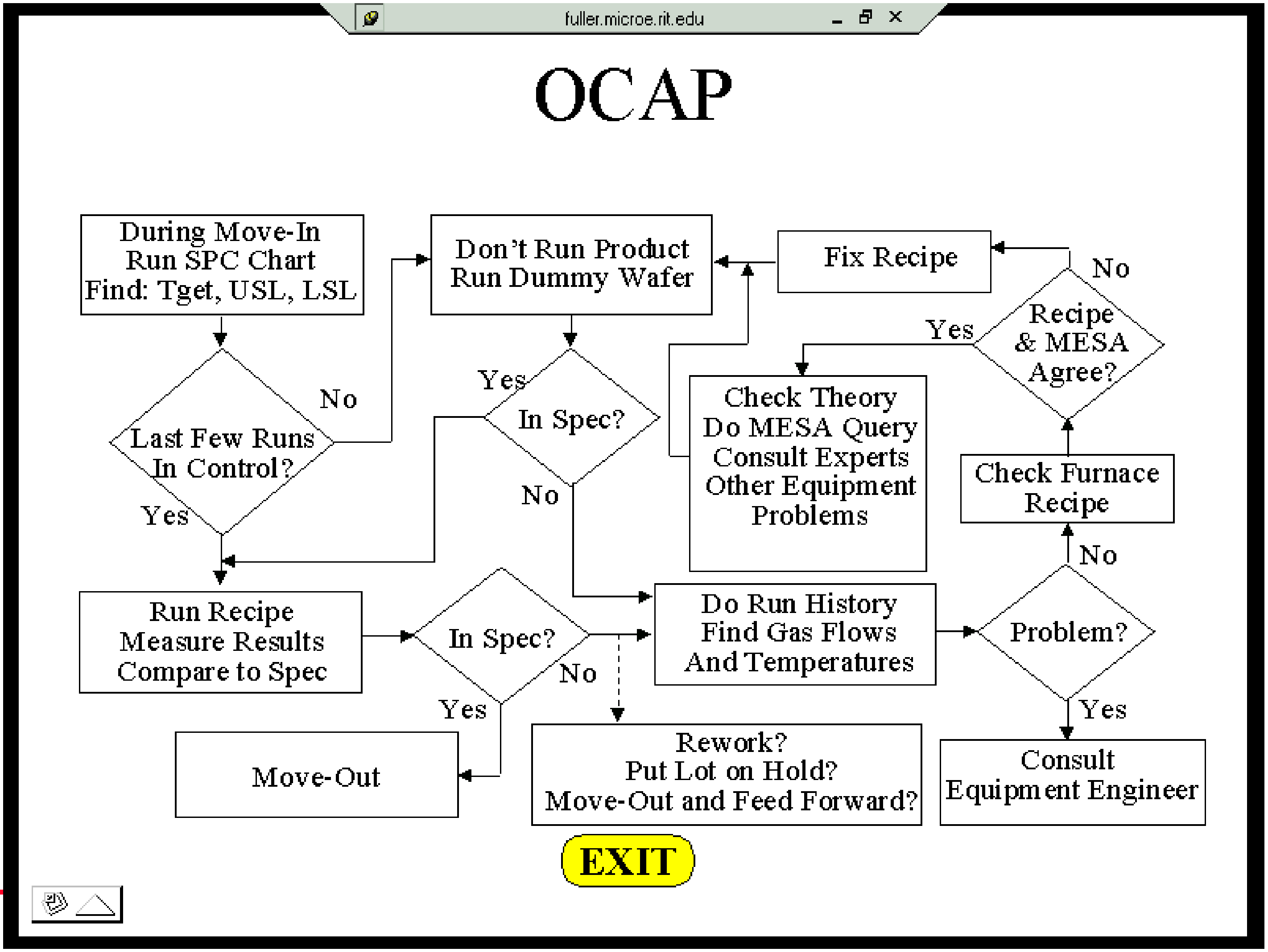
OUT OF CONTROL CRITERIA

- **Zone Rules: (Western Electric)**
  - when N out of M points are inside a zone (or outside a zone) relative to the center line and control limits of the chart. Zone boundaries are in multiples of sigma.
  - example: 2 of 3 points above or below +/- 3σ
  - example: 5 points in a row above or below target
- **Run Rules:**
  - when N points in a row are increasing, decreasing or alternating

    increasing/decreasing indicates process drift

    alternating indicates possible equipment problem

OUT OF CONTROL ACTION PLAN



SECTOR ENGINEERS

Sector Engineers Maintain Ownership of Specific Processes Belonging to that sector:

- Photolithography
- LPCVD
- Plasma Etch
- Metrology
- Oxidation & Diffusion, RTP
- Clean & Wet Etch
- Metal Deposition
- Ion Implant
- Maskmaking

Responsibilities Include:

- Product Inspection
- Monitor Process Performance (SPC)
- Process Capability Analysis (Cpk, Cp, K)
- Implement Action Plans for Improvement
- Coordination of Test Runs and Tool Calibrations

RESULTS

- A Methodology for Improving Manufacturing Quality in a Student-Run IC Factory has Been Outlined
- We Have Shown Improvements in Process Capability in Most Key parameters Over Recent Years
- We Have Developed a CIM System for Manufacturing Execution and TQM

FUTURE WORK

- Continue to Improve Towards 6 Sigma
- Integrate 6 Sigma and TQM Concepts in our Semiconductor manufacturing Courses
- Predict Circuit Performance Based on Knowledge of Process Variation

CONCLUSION

- The CIM System is Essential for a Project Such as This
- Very Interesting Project
- Useful as an Educational Tool for Teaching
  - Statistical Process Control
  - TQM
  - Six Sigma Manufacturing
  - Microelectronics Manufacturing
- Open Ended Project

REFERENCES

1. Western Electric Guide to Quality Control
2. “Control Chart Techniques for High Volume, Multiple Process Wafer Fabrication Areas”, Tom Bassett III, Signeteics Corp., IEEE/SEMI Advanced Semiconductor Manufacturing Conference, 1991.

HOMEWORK - Cpk

1. On the next pages you are given the latest data from a data base query for some or our 30+ p-well CMOS process key parameters. Given the target, USL and LSL, use a spreadsheet to calculate Cp, K, and Cpk for each parameter.

2. Make a plot of the data for one or more key parameters and compare it to a theoretical plot for a 6 sigma data distribution.

3. Discuss your results, which parameters are best, worst. Make suggestions on making improvements.

KEY PARAMETER TARGETS, USL, LSL

Name	Units	Target	LSL	USL
Alignment Oxide	Å	5000	4500	5500
Pad Oxide Thickness	Å	500	450	550
Nitride Thickness	Å	1500	1000	2000
Field Ox Thickness	Å	10000	9000	11000
Photo x-overlay	µm	0	-2	2
Photo y-overlay	µm	0	-2	2
Kooi Ox Thickness	Å	1000	900	1100
Gate Ox Thickness	Å	500	450	550
Poly Thickness	Å	6000	5000	7000
Poly Sheet Rho	ohms	25	10	50
LTO Thickness	Å	4000	3000	5000
Metal Thickness	Å	7500	5000	10000
Rho n+	ohms	25	10	50
Rho p+	ohms	25	10	50
Rho metal	ohms	0.1	0.05	0.5
Gc met-N+	mhos/um2	1	0.1	10
Nmos Vt	Volts	1	0.5	1.5
Nmos Sub Vt Slope	mV/dec	100	75	125
Nmos Imin	nAmps	1	0.01	100
Pmos Vt (magnitude)	Volts	1	0.5	1.5
Pmos Sub Vt Slope	mV/dec	100	75	125
Pmos Imin	nAmps	1	0.01	100
Vinvert	Volts	2.5	2	3

DATA

Alignment Oxide	6900 4846 4941 4097 4282 5243 4035 5449 4928 4505 4905 4323 3959 5243 5214
Pad Oxide Thickness	511 530 594 481 514 500 490 365 479 484 522 513 455 605 511
Nitride Thickness	1185 1539 1947 1150 1199 957 1200 1968 1500 1750 1300 1250 1585 1510 1354
Field Ox Thickness	10874 9660 10443 10489 9546 10711 10743 11651 9455 11357 10987 10966 11160 10957
Photo x-overlay	2 1 1 2 1 2 -1 1 -1 0 0 1 0 -1 1
Photo y-overlay	1 1 1 0 2 0 1 -1 -1 -1 0 0 0 -1 0
Kooi Ox Thickness	804 750 902 814 717 1056 981 1200 869 690 1078 856 809
Gate Ox Thickness	601 494 503 484 443 430 503 495 499 508 496 529 525 471 406
Poly Thickness	5723 6272 6635 6652 6442 7185 6089 4383 5656 4607 5107 5003 4838 5850 6054
Poly Sheet Rho	24 32 18 27 72 55 16 15 22 32 15 16 14 12 18
LTO Thickness	4570 2282 3166 4913 3724 7356 5318 4616 6700 4479 3386 1977 4000 3671
Metal Thickness	4000 5000 4000 7600 6500 7500 7800 7500 8000
Rho n+	21 22 28 27 24 33 17 24 25 22 20 26
Rho p+	44 91 36 70 54 28 25 25 35 26 23
Rho metal	0.06 0.09 0.05 0.01 0.15 0.14 0.1 0.11 0.16 0.19 0.14
Gc met-N+	1.1 1.3 5.0 0.5 3.3 4.6 5.5 7.8 1.5
Nmos Vt	0.76 0.82 1.05 1.12 1 0.57 1.59 1.03 1.6 2 2.11 1.5
Nmos Sub Vt Slope	100 116 100 250 200 120 92 110 75
Nmos Imin	1.0 0.1 0.01 1 10 1 0.1 0.1 1 1 0.1 0.001
Pmos Vt (magnitude)	1 1.5 0.31 0.8 0.6 1 1.27 0.44 0.1 0.5 0.6
Pmos Sub Vt Slope	112 95 92 125 92 86 150 112
Pmos Imin	10 10 10 100 100 10 10 10 100 10 100 10
Vinvert	3.8 1.9 2.5 3 2.5 2.8 2.9 2.5 2.8