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AEC/APC Symposium XV

Advanced Process Control Implementation in Plasma Etch at Infineon Technologies Richmond

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Never stop thinking.

Presentation Agenda

- Presentation Objective
- About the Environment
- The Opportunity in Plasma Etch
- Our Vision of APC
- An Implementation in 3 Phases
- Applications and Operational Benefits
- Conclusions
- Acknowledgements

Presentation Objective

- Share the IFR Plasma Etch APC experience

- Help the community learn from our successes and failure

Tell the Decision Makers:

- Return on Investment (ROI) can be achieved with APC

Encourage the Doers:

- Focus on ROI to make APC happen in your Fab

About the Environment

Infineon Technologies Richmond

- 200mm CMOS Fab (1st Si in March 1998)
- Deep tren
- 140nm tec

Plasma etch

- Process, e
- > 20 manu
- >10000 wa … tage
- >180 process/chamber combinations under control
- >170 product/parameter combinations under control

<u>Assuming</u>
300 die per wafer
$2 per die

1 scrap lot (25 wafers)
=
$15 000 revenue

About the Environment

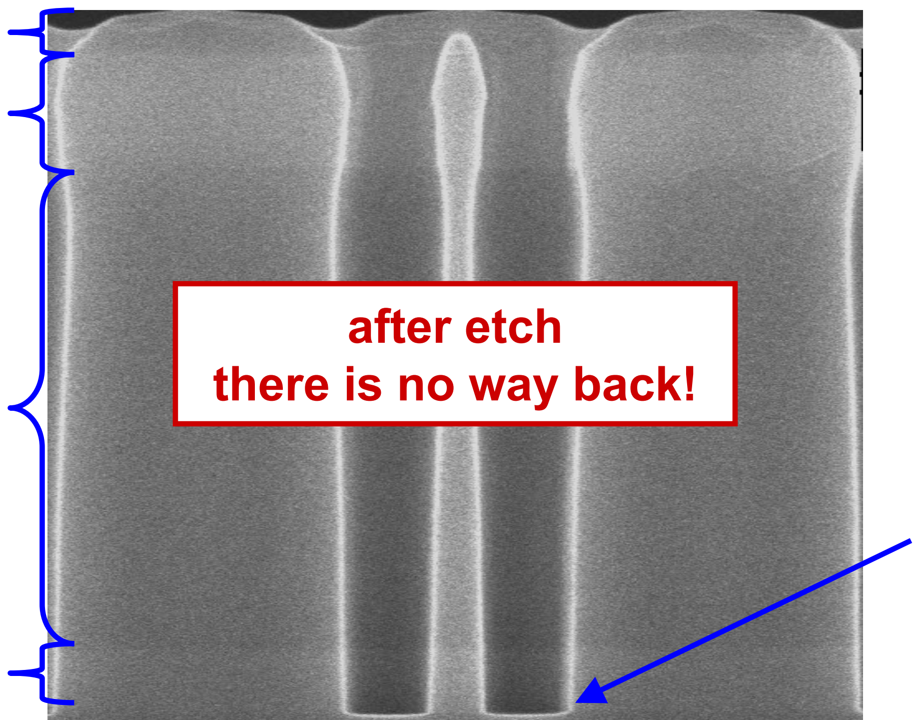
Where we came from

- Statistical process control (SPC) on in-line product data
- Equipment health monitoring through blanket wafer qualifications
- Activity based preventive maintenance
- Unscheduled maintenance driven by excursions (SPC, parametric or yield) and hard tool faults

The Opportunity in Plasma Etch

- Irreversible yield critical process
- Sensitive to all incoming variations
- 3-dimensional process output limits the ability of metrology to represent process health and predict yield

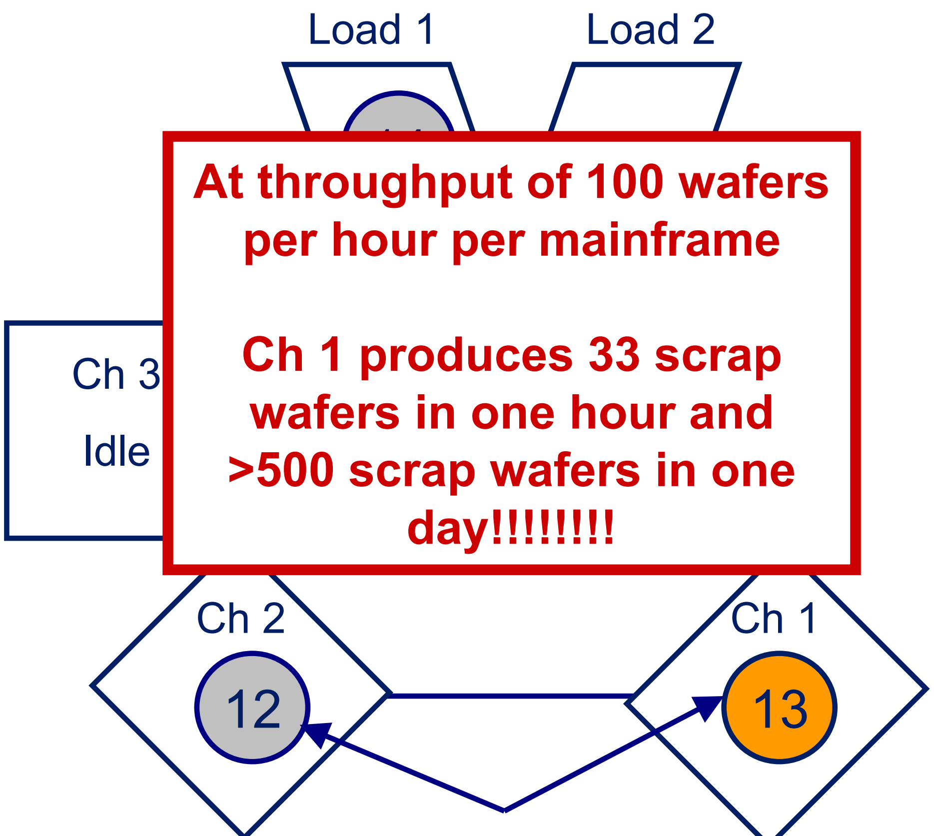
film thickness and composition effect etch



etched feature dimensions an shape must fit

The Opportunity in Plasma Etch

- Single wafer processing is the rule
- Multiple tool subsystems act independently and/or interact with each other to impact yield



At throughput of 100 wafers per hour per mainframe

Ch 1 produces 33 scrap wafers in one hour and >500 scrap wafers in one day!!!!!!!!

Ch 1 goes bad on wafer 13. This could be caused by:

- Pressure
- Temperature
- Gas Flow
- RF power
- Magnetic Field
- **… or a combination of …**

The Opportunity in Plasma Etch

More data

needed from

More sources

Our Vision of APC

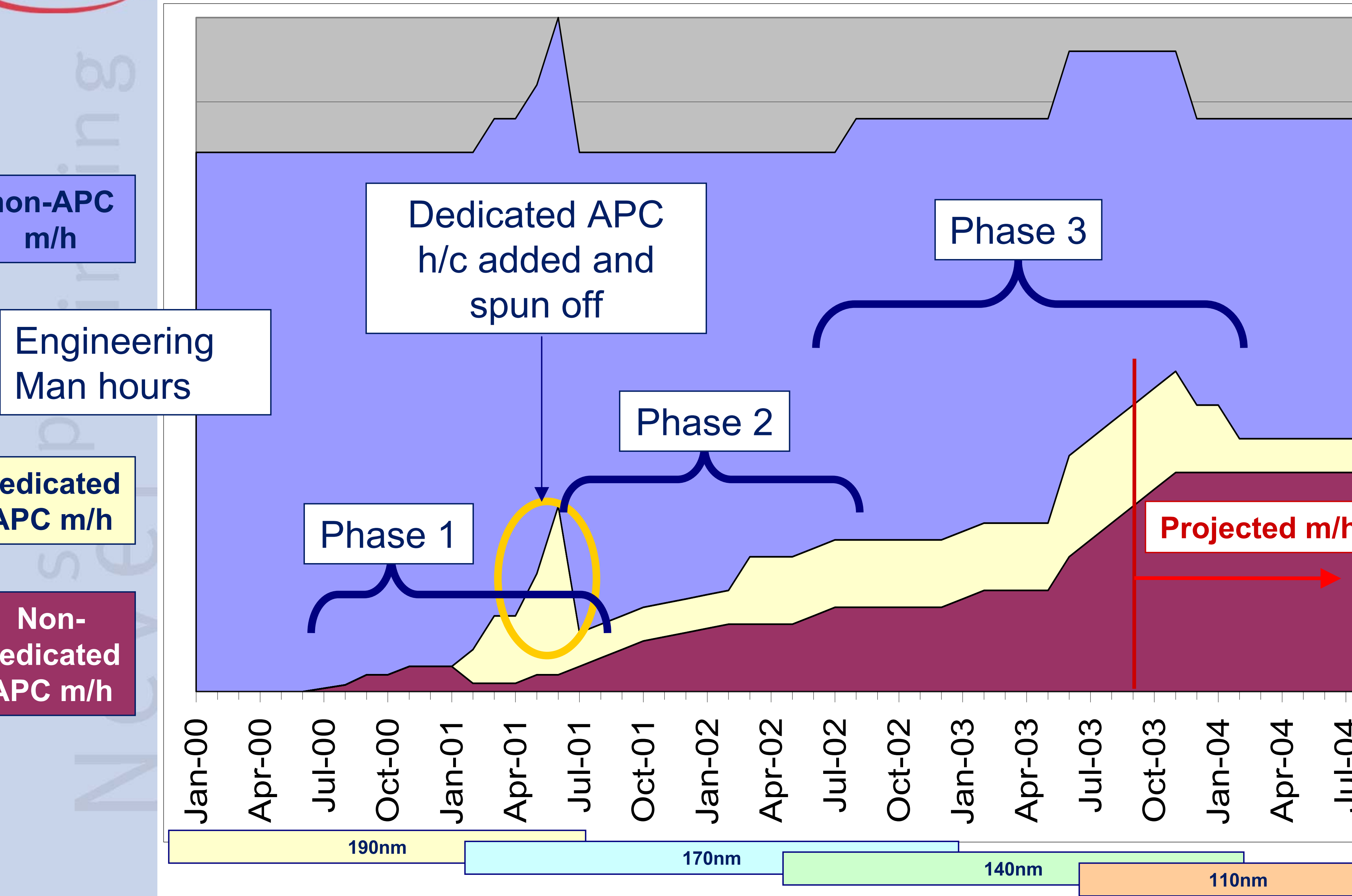
- Divergences from optimal conditions will be detected and compensated on first wafer **(FDC)**
- Every wafer leaves the Fab achieving its maximum yield potential – dynamic artisan processing **(R2R)**
- Capital equipment time will be utilized solely for production or predictive maintenance **(OEE)**
- Metrology will be a value added process **(R2R)**

Our Vision of APC

Future Considerations

- APC systems should be scaleable
- Wafer level ➔ Fab Cluster level
- High volume commodity products ➔ Complex multi-generational portfolios

An Implementation in 3 Phases

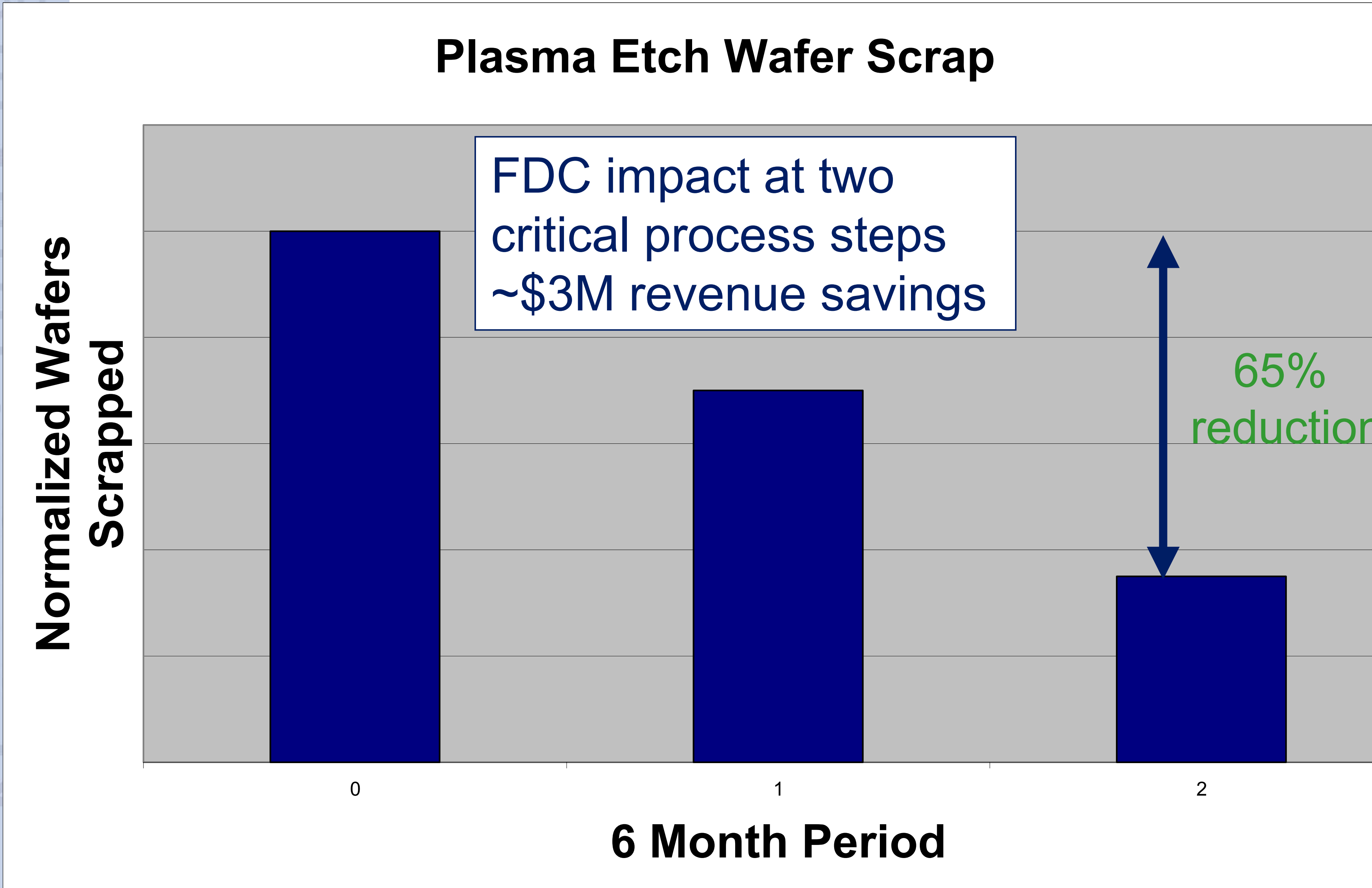


An Implementation in 3 Phases

Phase 1 – Demonstrate Return On Investment (ROI)

- Reduce scrap with FDC
  - Deep trench and metal etch
  - ~$3M revenue savings over 12 months
- Increase yield with R2R
  - Shallow trench isolation depth control
    (Jowett and Morozov, "Shallow Trench Isolation Run–to–Run Control Proje at Infineon Technologies Richmond", ASMC 2002)
  - 3% yield increase over 2 technology nodes
- Identify infrastructure and database requirements
- Justify additional resource allocation

An Implementation in 3 Phases



An Implementation in 3 Phases

Phase 1 – Demonstrate Return On Investment (ROI)

- Obstacles
  - Inertia – reliance on traditional paradigm
  - Skepticism – uncertainty of new paradigm
  - Skills gap – no experience in APC
- How We Overcame Them
  - Charismatic project manager
  - Small team of consensual junior engineers
  - Utilized internal competence centers
  - Workshops and conferences
  - Hired for missing skills

An Implementation in 3 Phases

Phase 2 – Develop Infrastructure and Applications

- Develop infrastructure based on Phase 1 learning
  - Equipment to CIM communication
  - Server hardware upgrades for functionality
  - "Tool server" creation for each vendor mainframe
- Hardware and software training for engineers
  - Data access
  - Data handling and manipulation
- Identify applications for automation and roll-out
- Justify additional resource allocation

An Implementation in 3 Phases

Phase 2 – Develop Infrastructure and Applications

- Obstacles
  - Unrealistic expectations
  - Multiple databases with incompatible data structure
  - Lack of resources both capital and human
- How We Overcame Them
  - Prioritized projects
  - Pareto and FMEA
  - Included product yield and quality groups
  - Focused on ROI as top priority

An Implementation in 3 Phases

Phase 3 – Automate Applications and Rollout Area-wid

- Automate four applications
  - Statistical machine control (FDC)
  - SPC by chamber (FDC)
  - Run to run (R2R)
  - Qual elimination (OEE)
- Monitor progress and stay on timeline
- Justify additional resource allocation

An Implementation in 3 Phases

Phase 3 – Automate Applications and Rollout Area-wid

- Obstacles
  - Lack of capital
  - Lack of human resources
  - Managing a large quantity of milestones
- How We Overcame Them
  - Focused on ROI
  - Created a graphical metric
  - Tracked unique milestone completion

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An Implementation in 3 Phases

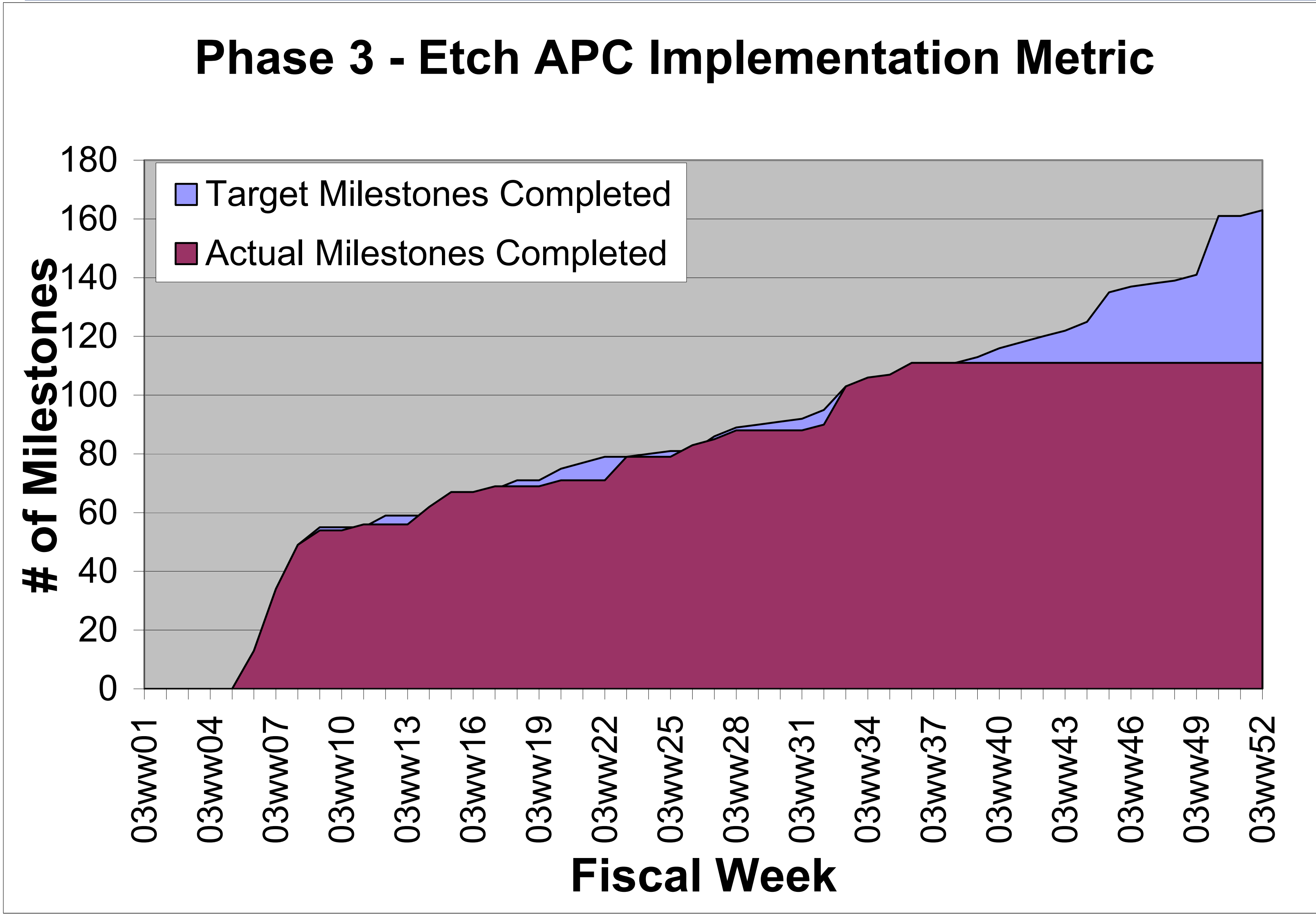
Phase 3 – APC Implementation Metric

Item #	Process	Target Completion Week							
		SMC Capability	EP logbooks	Chamber EP Data	SPC by Chamber	Etchrate Qual Elimination	Particle Qual Elimination	SMC Methods	Run to R
1	Proc1	03ww06	03ww07	03ww08	03ww09	03ww45	03ww50	03ww45	
2	Proc2	03ww06	03ww07	03ww08	03ww09	03ww27	03ww50	03ww37	03ww44
3	Proc3		03ww07	03ww08	03ww28			03ww41	
4	Proc4	03ww06	03ww07	03ww08	03ww33	03ww45	03ww50	03ww45	
5	Proc5	03ww18	03ww07	03ww20	03ww28	03ww45	03ww50	03ww44	

Item #	Process	Actual Completion Week							
		SMC Capability	EP logbooks	Chamber EP Data	SPC by Chamber	Etchrate Qual Elimination	Particle Qual Elimination	SMC Methods	Run to Ru
1	Proc1	03ww06	03ww07	03ww08	**03ww33**	03ww32			
2	Proc2	03ww06	03ww07	03ww08	03ww09	**03ww33**			
3	Proc3		03ww07	03ww08	03ww26				
4	Proc4	03ww06	03ww07	03ww08	03ww26	03ww33			
5	Proc5	03ww14	03ww07	03ww20	03ww26	03ww33			

> 20 processes total

An Implementation in 3 Phases



Applications and Operational Benefits

- **Wafer-chamber data enabled chamber level yield tracking and improved troubleshooting**

ETCH Tool: AMTZ04FC   Recipe: EA101.03

Wfr#	Chamb	OARC Time	BSG,NIT Time
25	B	69.80	104.10
24	A	71.10	103.20
23	C	68.90	106.50
22	B	70.20	103.20
21	A	70.80	103.60
20	C	69.40	106.20
19	B	69.40	104.20
18	A	71.40	103.20
17	C	68.80	107.00
16	B	69.90	104.60
15	A	70.90	102.80
14	C	69.10	106.60

Lot Statistics

Chamber A			
OARC Mean:	71.1	Rf Tot:	.
OARC Range:	0.6		
BSG,NIT Mean:	103.5	Rf WC:	43.0
BSG,NIT Range:	2.6		
STEP 3 Mean:	.		
STEP 3 Range:	.		

Chamber B			
OARC Mean:	69.6	Rf Tot:	.
OARC Range:	1.3		
BSG,NIT Mean:	103.9	Rf WC:	161.0
BSG,NIT Range:	3.0		
STEP 3 Mean:	.		
STEP 3 Range:	.		

Applications and Operational Benefits

- **Product etchrate data enabled qual elimination**

ETCH Tool: DPSZ01EA Recipe: EG101.03
Diff Tool: NITRO5DB

		Diffusion			ARC EP	Etch	POLY HM EP
Wfr#	Chamb	Mean	Rng	1%sig	Time	Rate	Time
25	D	.	.	.	42.60	.	92.60
24	A	.	.	.	38.20	.	92.70
23	B	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	97.00
22	A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	93.80
21	B	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	96.60
20	A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	92.50
19	B	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	96.60
18	A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	93.50
17	B	.	.	.	[illegible]	.	97.60
16	A	.	.	.	38.10	.	94.30
15	B	.	.	.	38.70	.	95.80
14	A	2011.35	47.7	0.74	38.30	1303.25	92.60
13	B	.	.	.	39.10	.	96.60

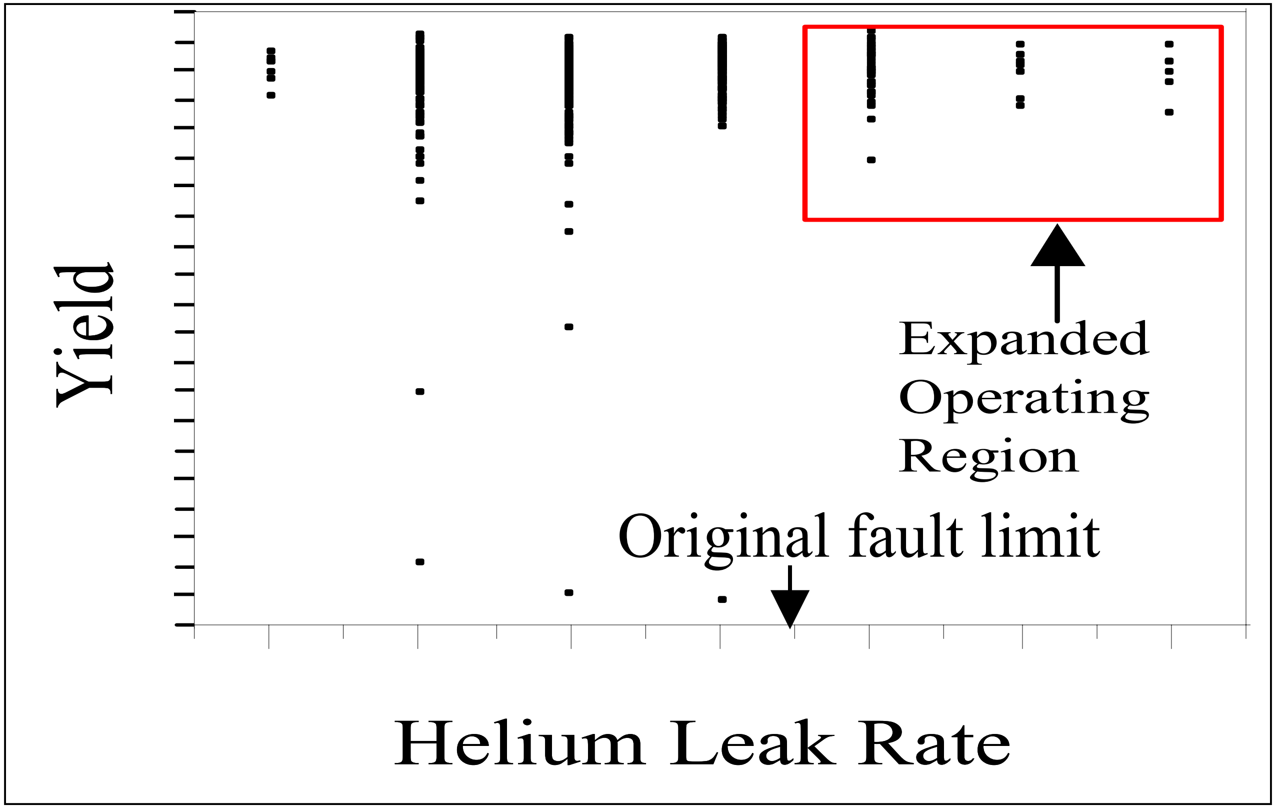
Chamber A

ARC EP Mean:	38.1	Rf Tot:	
ARC EP Range:	0.8		.
Etch Rate:	1303.3		
POLY HM EP Mean:	92.6	Rf WC:	
POLY HM EP Range:	3.7		128.0

- **Availability to production increased by 2% on averag test wafer usage reduced by 80% and associate productive time was increased**

Applications and Operational Benefits

- **SMC data enabled improved fault management for OE and predictive maintenance without loss of resolutio**

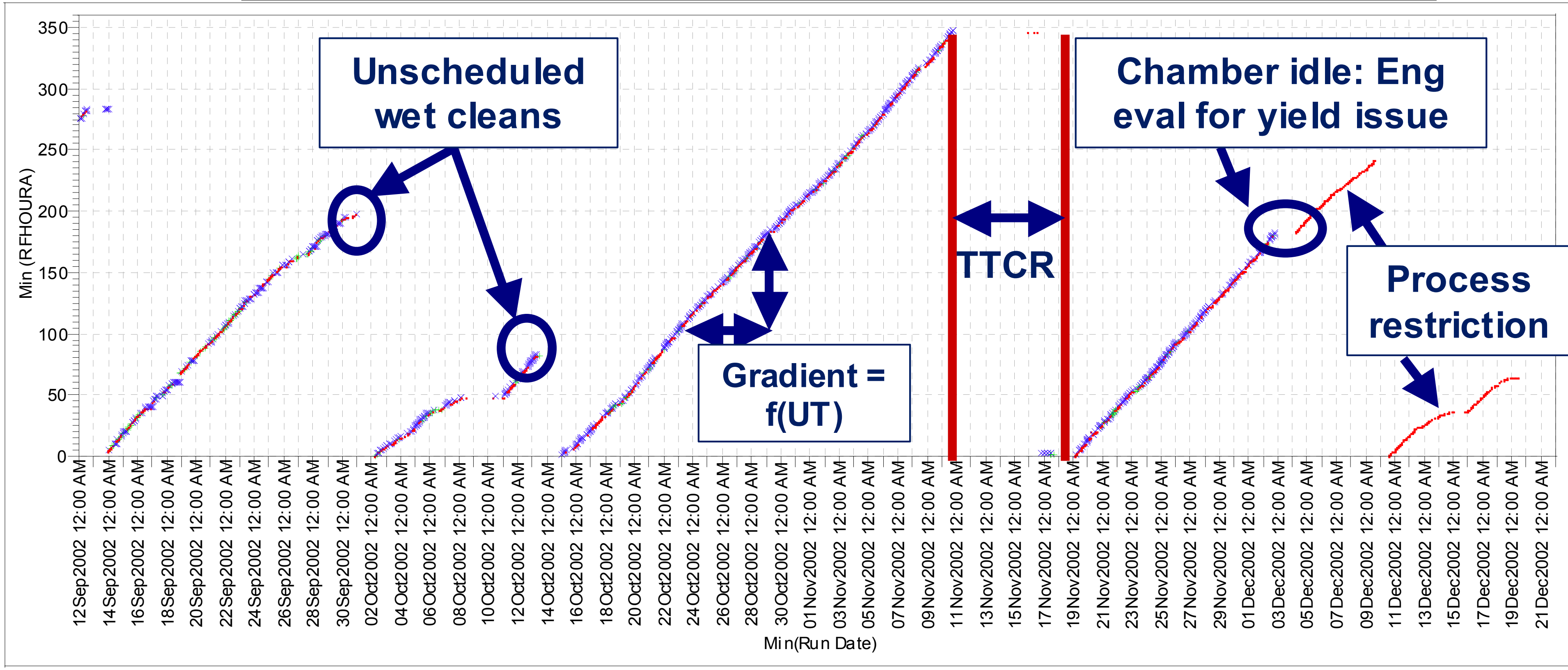


- **Allowing production in the expanded operating regio increased availability by 1% and yield by 0.1%**

Applications and Operational Benefits

- **SMC data provided context to OEE statistics**

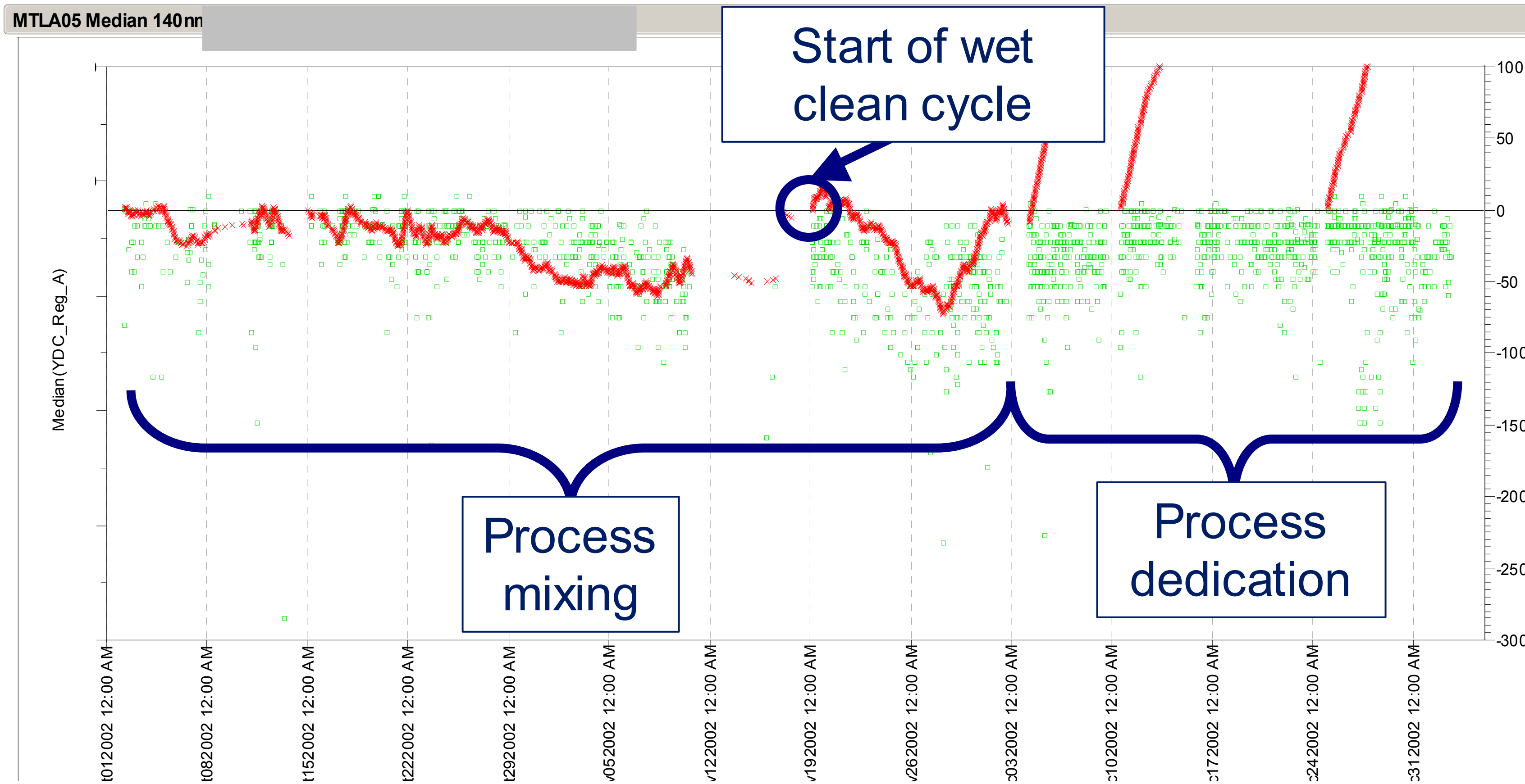
Productive Wafers	Idle Time	Eng	Unsch Down	Non Productive Wafers	PM
69.5%	6.9%	3.8%	18.4%	1.2%	0.2%



x – Process 1 + - Process 2 • - Process 3

Applications and Operational Benefits

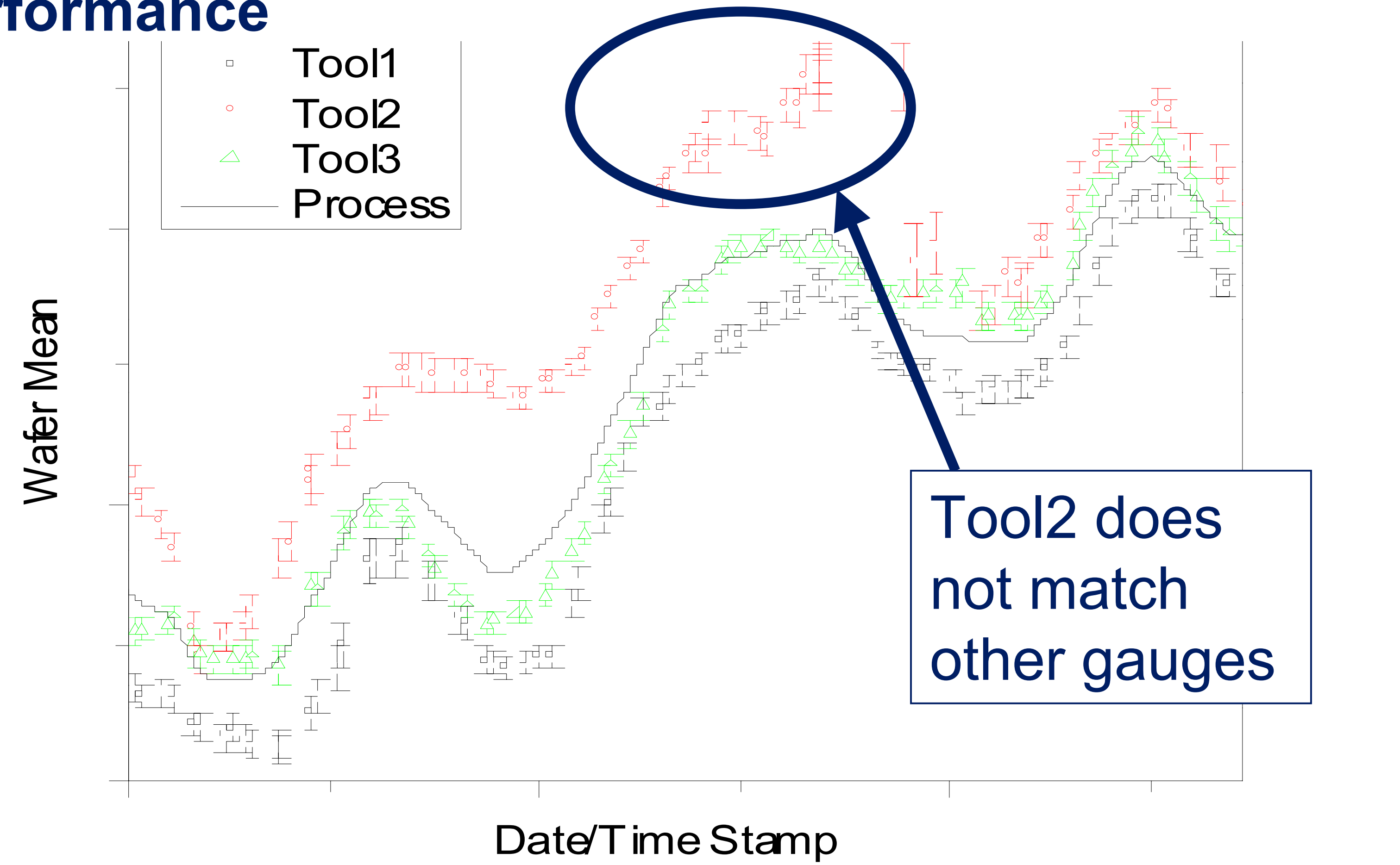
- **SMC data provided context to chamber yield performance**



- **Process dedication increased yield by 0.7%**

Applications and Operational Benefits

- **Systems and data for monitoring dynamic metrology performance**



Applications and Operational Benefits

- **Happier engineers**
  - Workload reduced by approx. 15%
  - Able to answer more questions
  - Able to prove the answer with data
  - Fewer excursions to clean up
  - More time to focus on interesting engineering projects **… like sensors!**

Conclusions

- **APC implementation was a long road (3+ years for reasonable functionality and process coverage)**
- **The payoff is worth the effort**
- **Operational benefits in addition to FDC and R2R will be obtained**
- **Focus on ROI to overcome obstacles**
- **We still have not reached the final destination**

- **Next step – sensor integration??$$??**

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Acknowledgements

- **Contributions to the success of APC in etch were made by:**
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References

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