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Unit process aspects for APC-software implementation

Georg Roeder, Martin Schellenberger, Lothar Pfitzner, Heiner Ryssel
Fraunhofer Institute of Integrated Systems and Device Technology (IISB), Erlangen, Germany

Gerhard Spitzlsperger
Renesas Semiconductor Europe (Landshut), Germany

Fraunhofer Institut Integrierte Systeme und Bauelementetechnologie

Unit process aspects for APC-software implementation

Motivation

Example process for APC application (RtR, FDC)

Influence of APC on process flow and logistics

RtR control and FDC strategies

Requirements on APC-software

Unit process aspects for APC-software implementation

Objectives

Evaluation of the requirements for the implementation of APC-software for

- integration into an existing IT and logistics structure
- integration into a high product mix fabrication environment

Investigations

Study of critical processes for APC application (RtR, FDC) on the

- influence of APC on process flow and logistics
- identification of RtR control and FDC strategies
- applicability of RtR and FDC algorithms in high product mix environments

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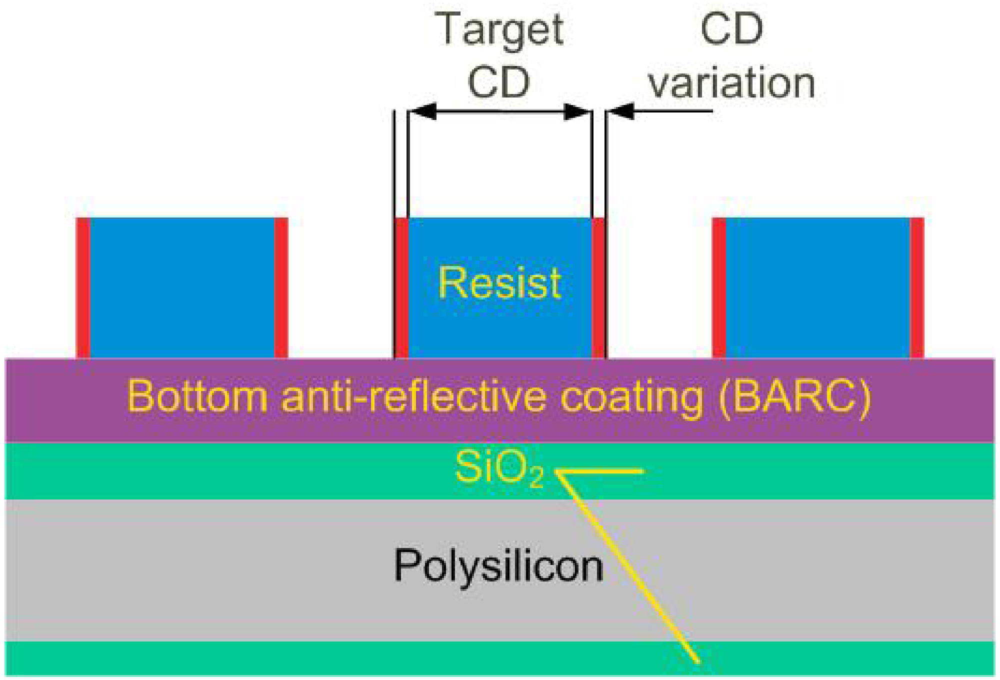
Application of APC in unit processes – poly-gate litho and etch sequence (1)

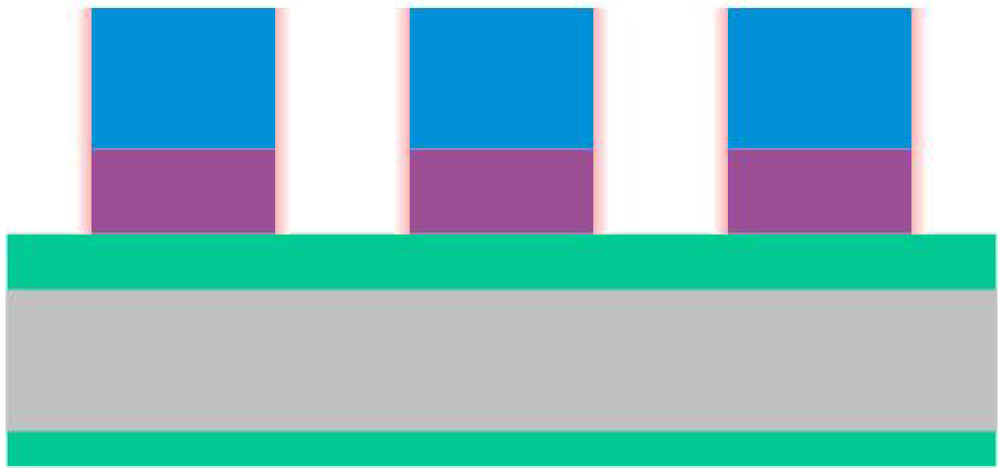
Lithography

Mask preparation for poly-gate etch



Etch

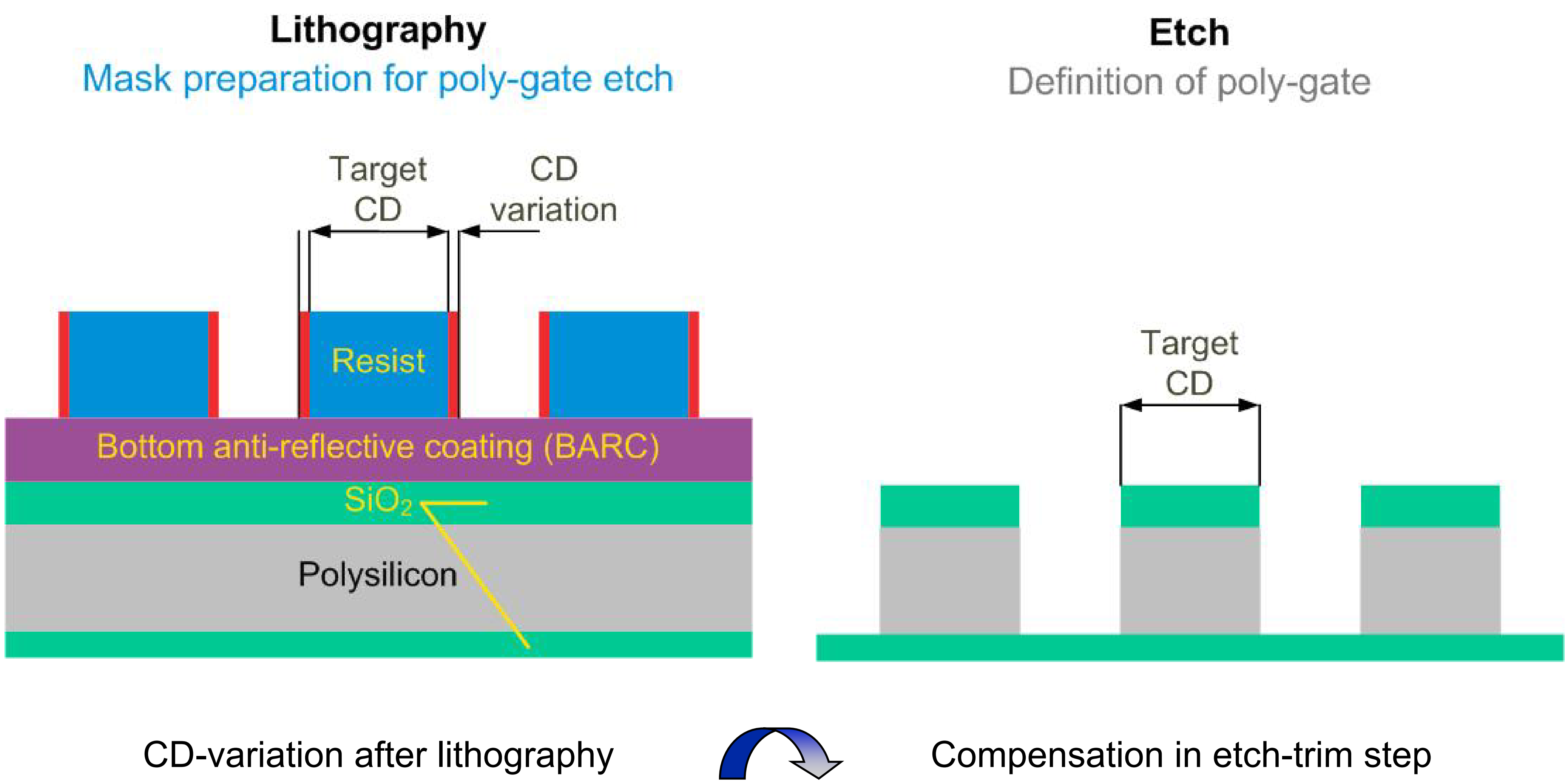
BARC-etch step



CD-variation after lithography

Compensation in trim step
by etch-time adjustment

Application of APC in unit processes – poly-gate litho and etch sequence (2)



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Feed-forward litho-etch-CD sequence using pre-selection of recipes

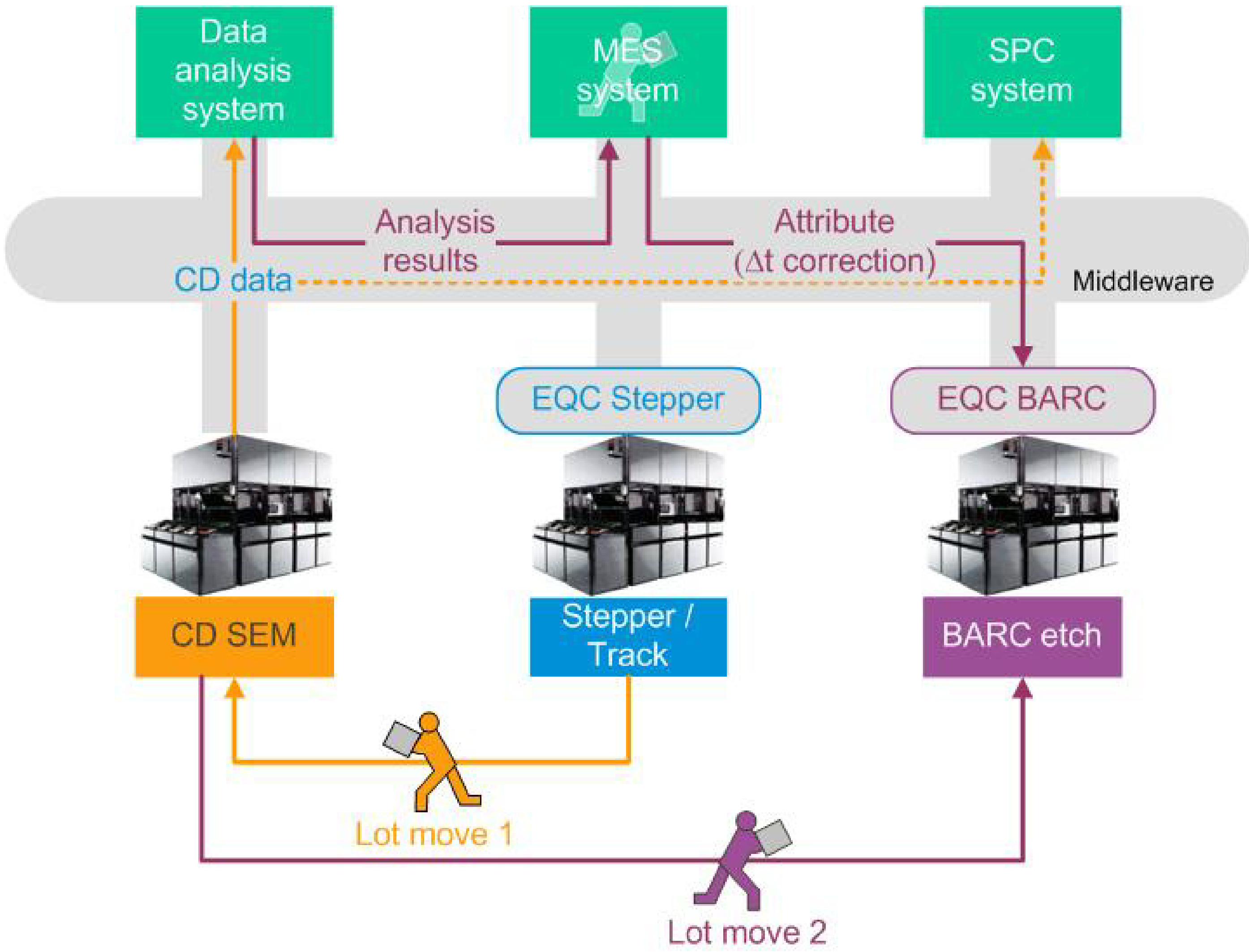
Lot exposure at stepper

Lot move to CD SEM; CD measurement; data transfer to data analysis system

Allocation of attribute in MES for selection of one out of three possible etch-times

Lot move to BARC-etch and manual selection of specific recipe according to MES attribute

- ⬆ Simple implementation
- ⬇ Discrete adjustment of etch-time
- ⬇ Manual interaction
- ⬇ Efforts, if implemented for various steps or products



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Feed-forward litho-etch-CD sequence using APC-software

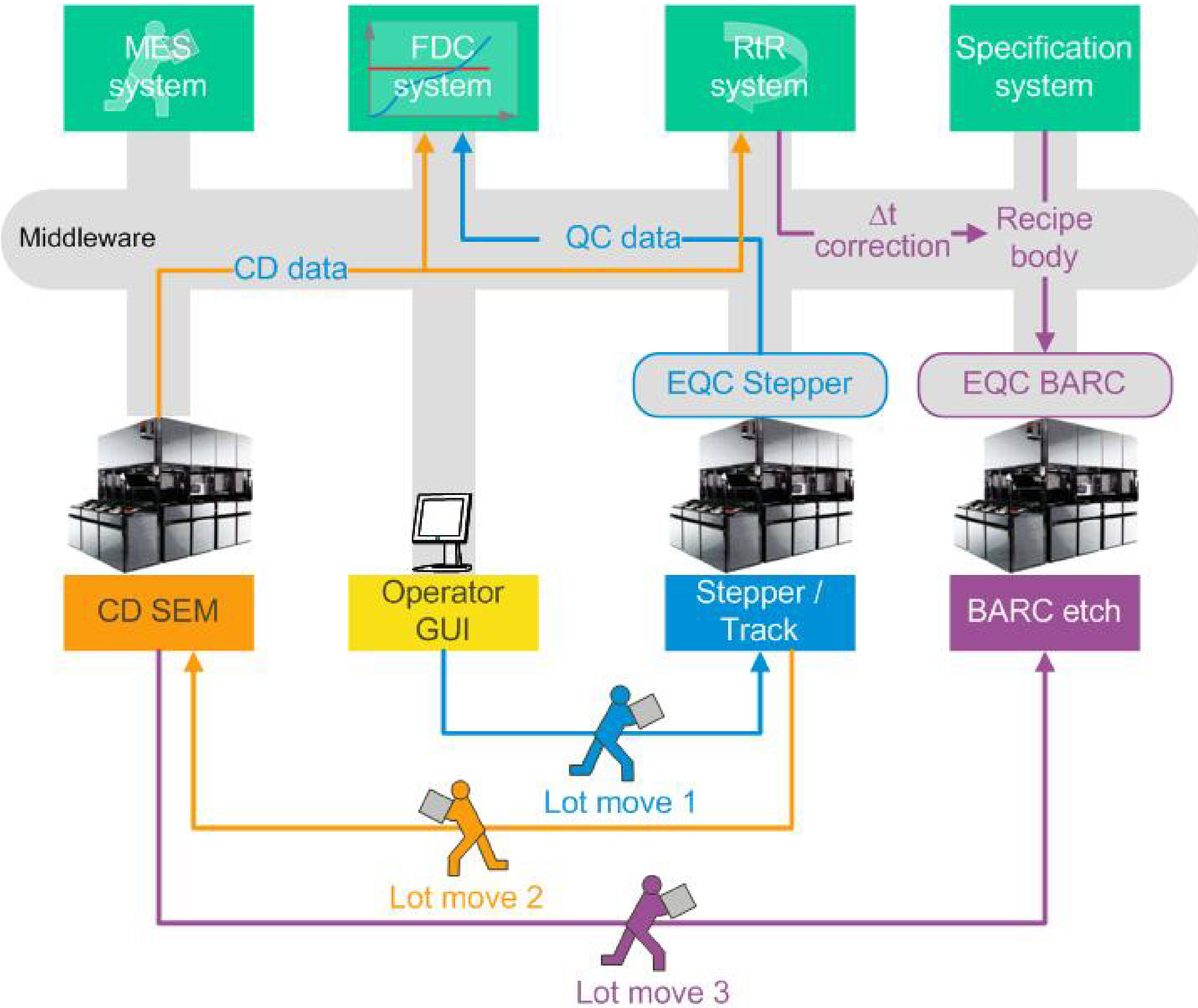
Manual lot move to exposure GUI via operator GUI; obtain correct exposure recipe

Stepper equipment data transfer to FDC system for analysis of resist open/not open

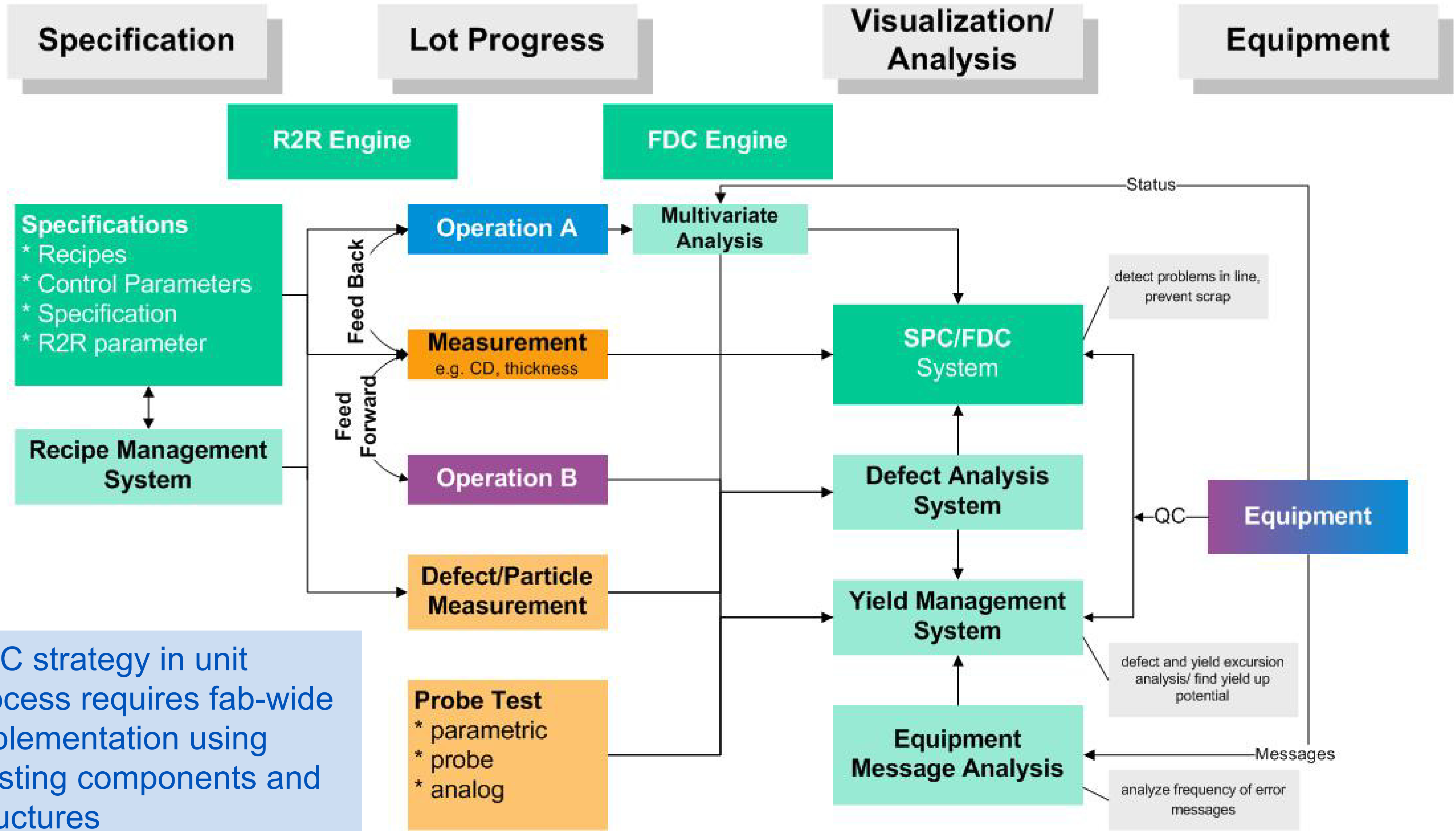
Lot move to CD SEM; CD measurement; data transfer to FDC and RtR system

Manual lot move to BARC-etch; equipment controller (EQC) retrieves recipe body from specification system and etch-time from RtR system

- Continuous adjustment of etch-time
- Automated procedure



IT structure and logistics for APC implementation



APC strategy in unit process requires fab-wide implementation using existing components and structures

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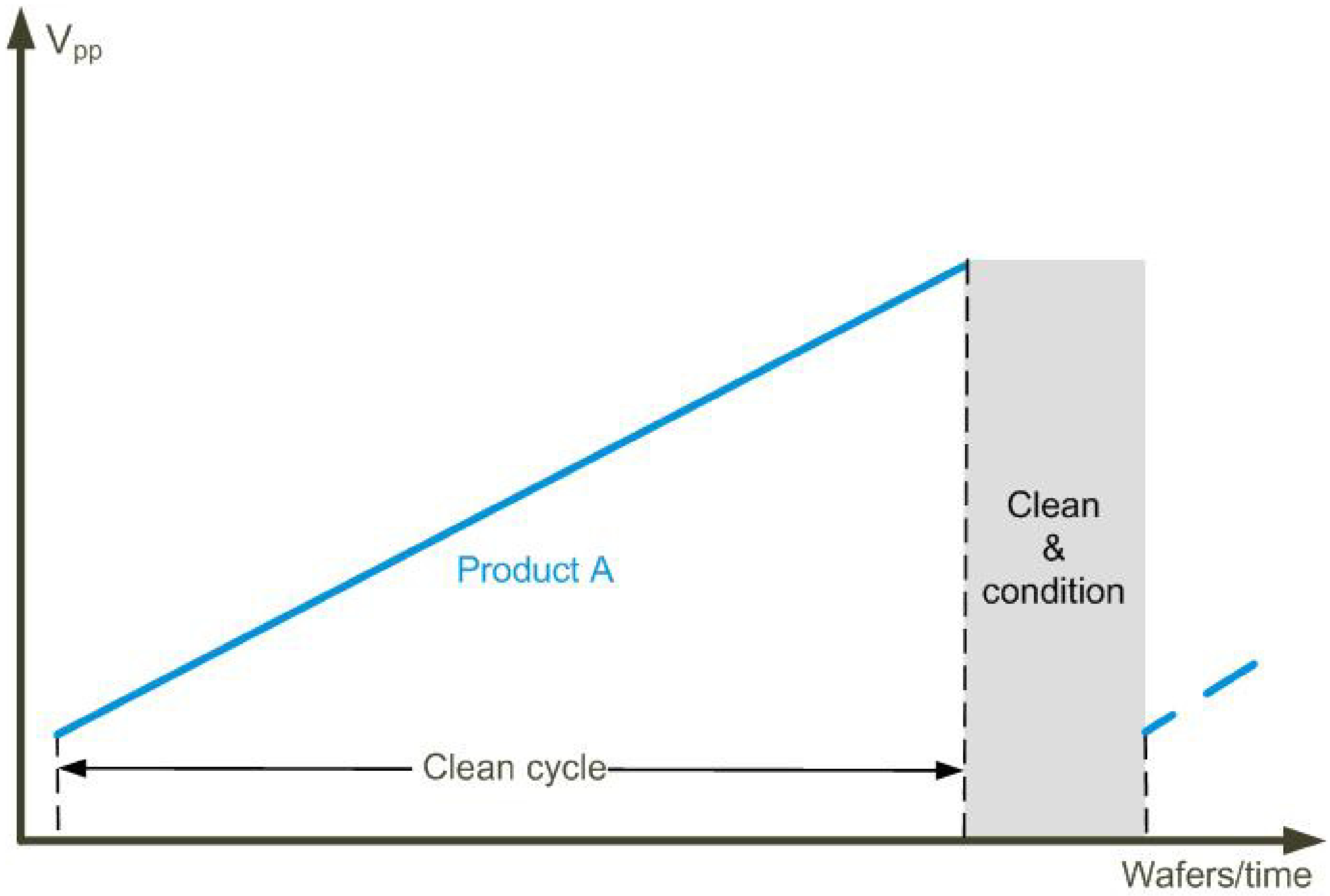
- Motivation
- Example process for APC application (RtR, FDC)
- Influence of APC on process flow and logistics
- RtR control and FDC strategies
- Requirements on APC-software

Adjustment of etch-time in low product mix environments

In the low product mix case, etch-time adjustments may be estimated as $\Delta t = f(CD_{Litho})$

Equipment state $\underline{P}_{eq}$ changes continuously within clean cycle and is reproducible from clean cycle to clean cycle

More precise adjustment is possible if chamber status is regarded, $\Delta t = f(CD_{Litho}, \underline{P}_{eq})$



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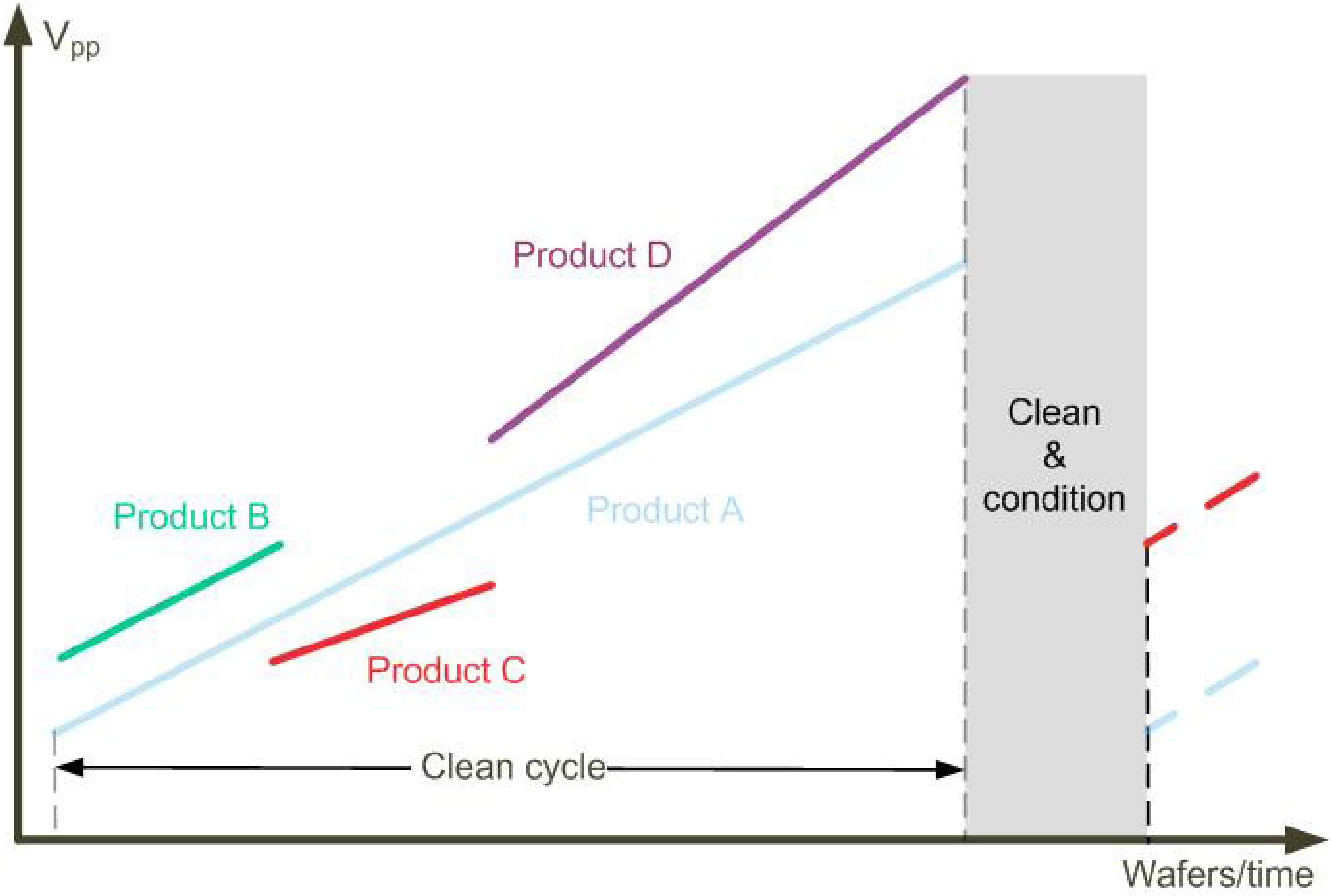
Adjustment of etch-time in high product mix environments

In the high product mix case, the equipment state changes discontinuously within clean cycle and is not reproducible from clean cycle to clean cycle

Etch-time adjustments are dependant on product and chamber status,
$\Delta t = f(CD_{Litho}, \text{product}, \underline{P}_{eq})$

Precise etch-time adjustment requires the

- determination of the chamber status
- extrapolation of chamber status for the following product and correction of Δt



Determination of chamber state and fault detection – process example

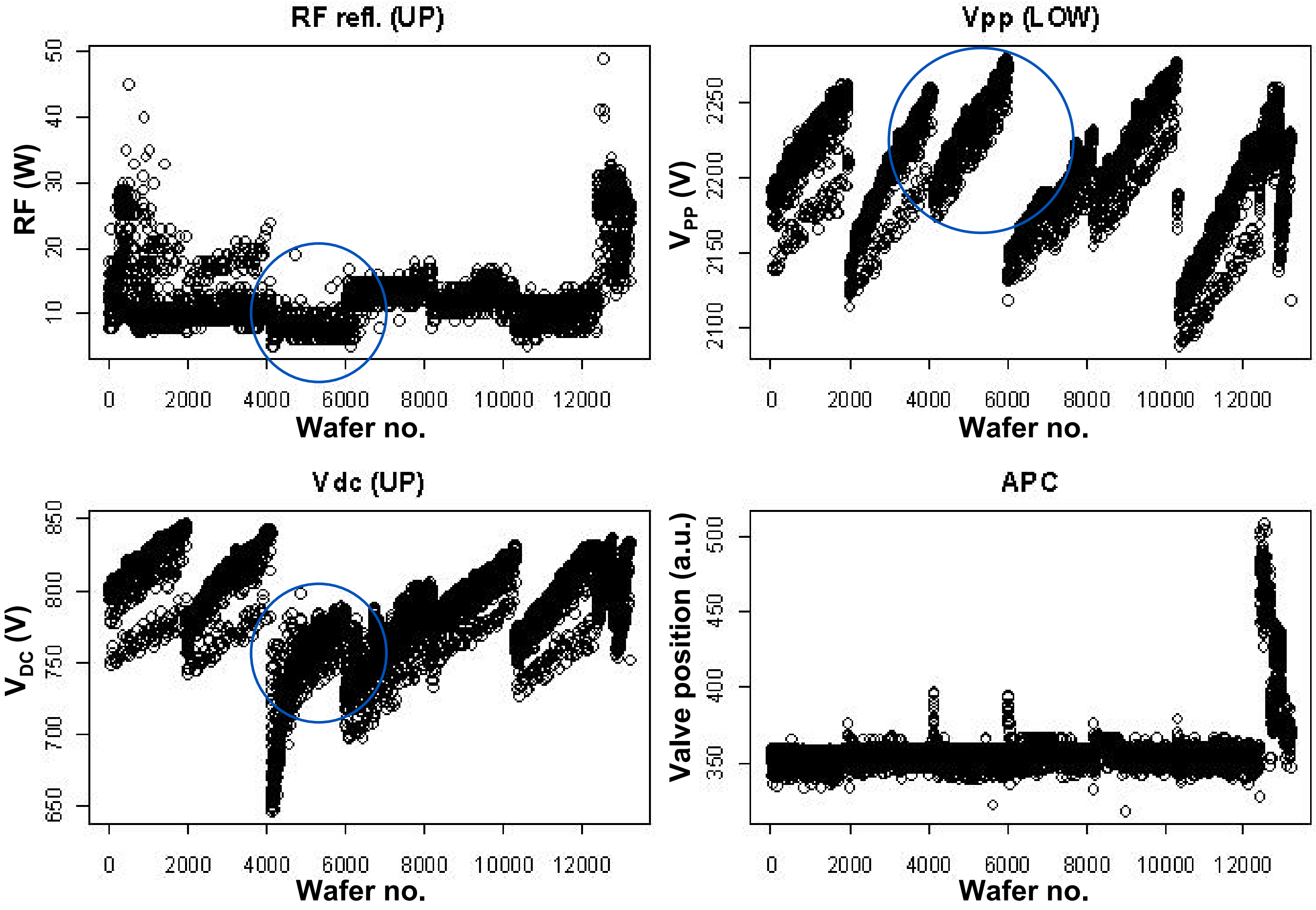
Via process with standard $Ar/C_4F_8/O_2$ chemistry (TEL Unity)

Analysis of available tool data (RF parameters, pressure, valve position, MFC openings, chamber temperatures)

Study of more than 13,000 wafers over six clean cycles (comparable products, same recipe)

Data includes three fault types

- bad RF matching at the upper electrode (50 wafers)
- insufficient conditioning after wet clean (3x, 51 wafers in total)
- process chamber leak due to breakage of EPD window (>700 wafers)



◯ Different spare part properties

Schmidt, C.; Bartl, S.; Speil, M.; Straßer, J.; Ernst, G.; Spitzlsperger, G.: *Fault Detection and Classification (FDC) for a Via-Etching-Process*. 5th European Advanced Equipment Control/Advanced Process Control (AEC/APC) Conference, Dresden, Germany, April 14-16, 2004.

Determination of chamber state and fault detection – data analysis

Analysis by PCA and T^2 statistics

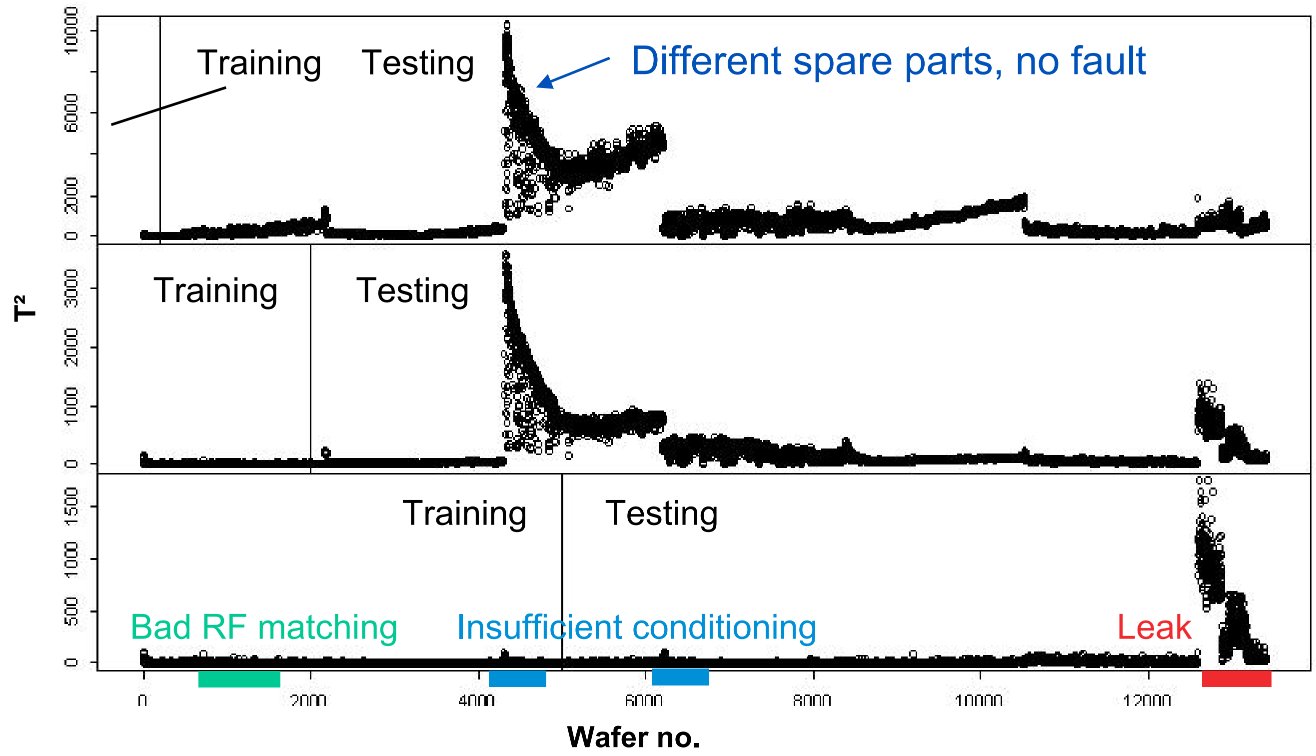
$$T^2 = z^T S^{-1} z$$

If no data reduction is performed, the determination of chamber state strongly depends on the size of the learning sample

- small training sample size: no estimation of alarm limits possible
- large training sample size: estimation of alarm limits possible

If data reduction is performed, the T^2 statistic has to be complemented by Q-charts to trace model residuals

→ medium training sample sizes become applicable



- Determination of chamber state requires high efforts even for one product
- Application of new adaptive multivariate methods for drift compensation and model update will be necessary
- Improved methods for chamber state determination are necessary for optimization of RtR control of litho-etch-CD

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General requirements for APC-software

- System must handle APC fab-wide
- APC system must fit to current IT-structure
- Performance requirements are specific for high product mix and low sample size (requires flexibility of algorithms and system)
- Low efforts for implementation, maintenance, and training
- Comprehensive support by APC-software supplier

Conclusions

APC implementation in unit processes requires fab-wide APC handling

Modular APC systems can be merged to existing IT-structure but significant implementation efforts may be necessary

Further research is required on data acquisition, determination of equipment states, and algorithms for APC in high product mix environments