The Challenge of Metrology in the 450 mm Wafer Transition Process

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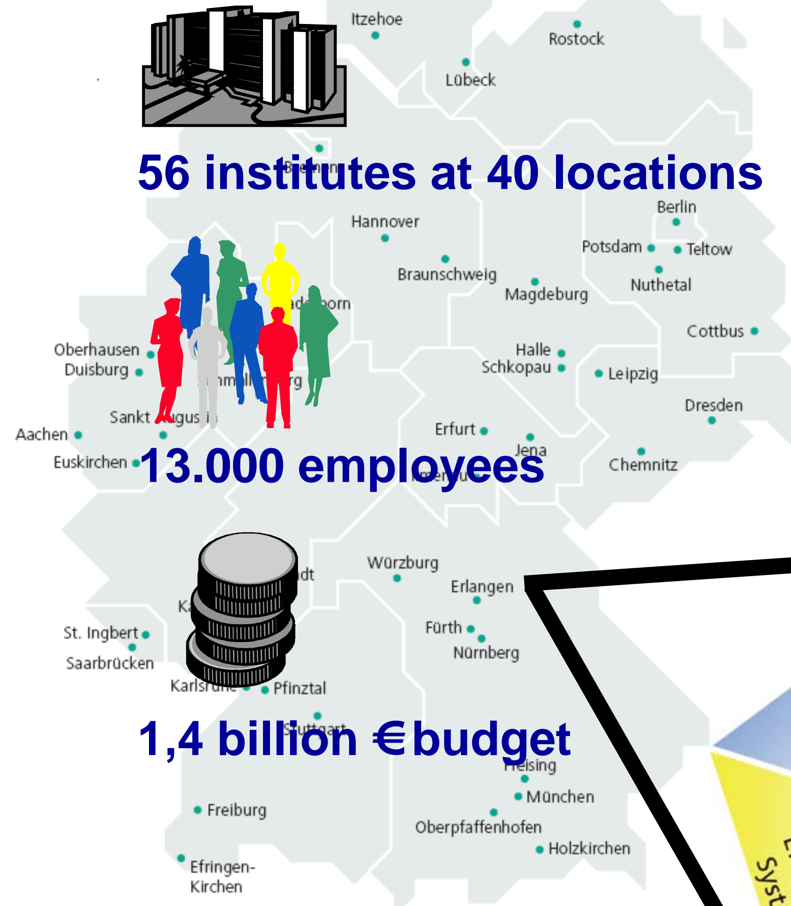

- ❒ Microelectronics
- ❒ Production
- ❒ Information and Communication Technology
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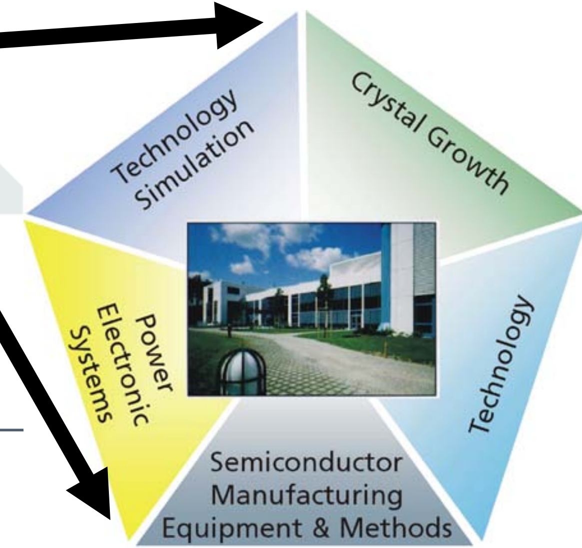

Outline

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  - Metrology in Production
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Introduction

Metrology:
(Greek) metron (measure)
+ *logos* (study of)

Metrology includes all theoretical and practical aspects of measurement.

Metrology

- “The science of measurement, embracing both experimental and theoretical determinations at any level of uncertainty in any field of science and technology.“

Characterization

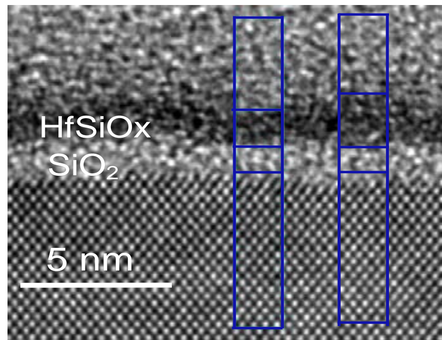
- “To describe the properties of a studied object by appropriate metrology”

Inspection

- „An inspection is, most generally, an organized examination or formal evaluation exercise. It involves the measurements, tests, and gauges applied to certain characteristics in regard to an object or activity. The results are usually compared to specified requirements and standards for determining whether the item or activity is in line with these targets. Inspections are usually non-destructive.”

source www.wikipedia.org (2009)

Introduction



HfSiOx: 1.4 ± 0.5 nm 2.1 ± 0.5 nm
SiO_2: 1.1 ± 0.5 nm 1.1 ± 0.5 nm

*Analysis at atomic scale performed with **XTEM** @ CNR & **MEIS** @ Daresburg Laboratory (USAL) (ANNA –project FP6 EC contract* 026134-RII3)

Metrology and Characterization in Nanotechnologies

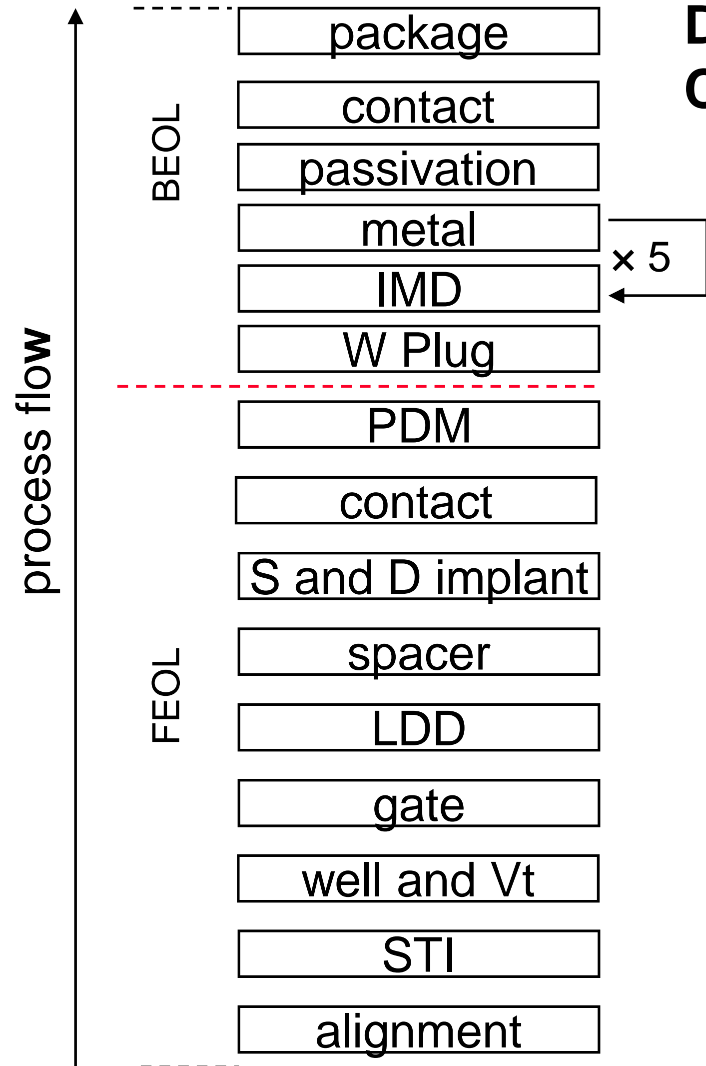
- understanding and controlling of dimensions, materials properties, and defects towards **atomic level** is required (e.g. 1.5 nm HfSiOx layer)
- **improving of capabilities** of metrology and analysis equipment (e.g. 3D at atomic scale) poses huge challenges

Semiconductor Manufacturing

- a series of processes with up to 1000 processing steps
- a series of interposed metrology and inspection steps

Metrology for semiconductor manufacturing comprises tackling of preparatory know-how, of off-line, in-line and *in situ* – characterization, and advanced process control (APC).

Introduction

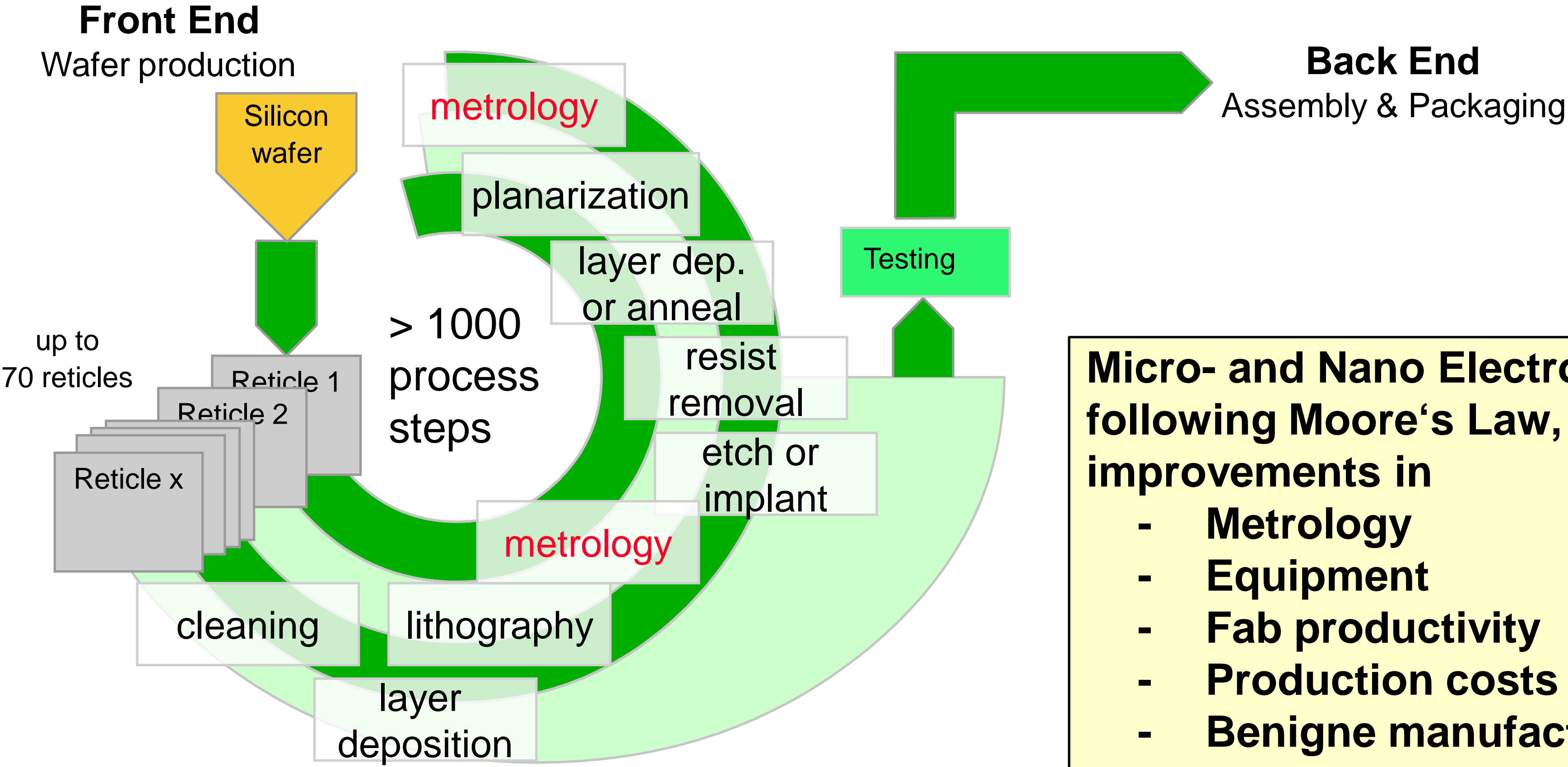


Defect and Failure Scenario of an Integrated Circuit

overlay
ESD Damage
Interconnects
crack
Metal 2
Via
short
particle
open
Metal 1
particle
layer thickness
p^+
n
n^+
p
p
COP
n-well
p-well
contamination
interfaces: roughness, state density, charges
Si crystal: stacking faults, contamination, stress, COP

Metrology ins Semiconductor Manufacturing

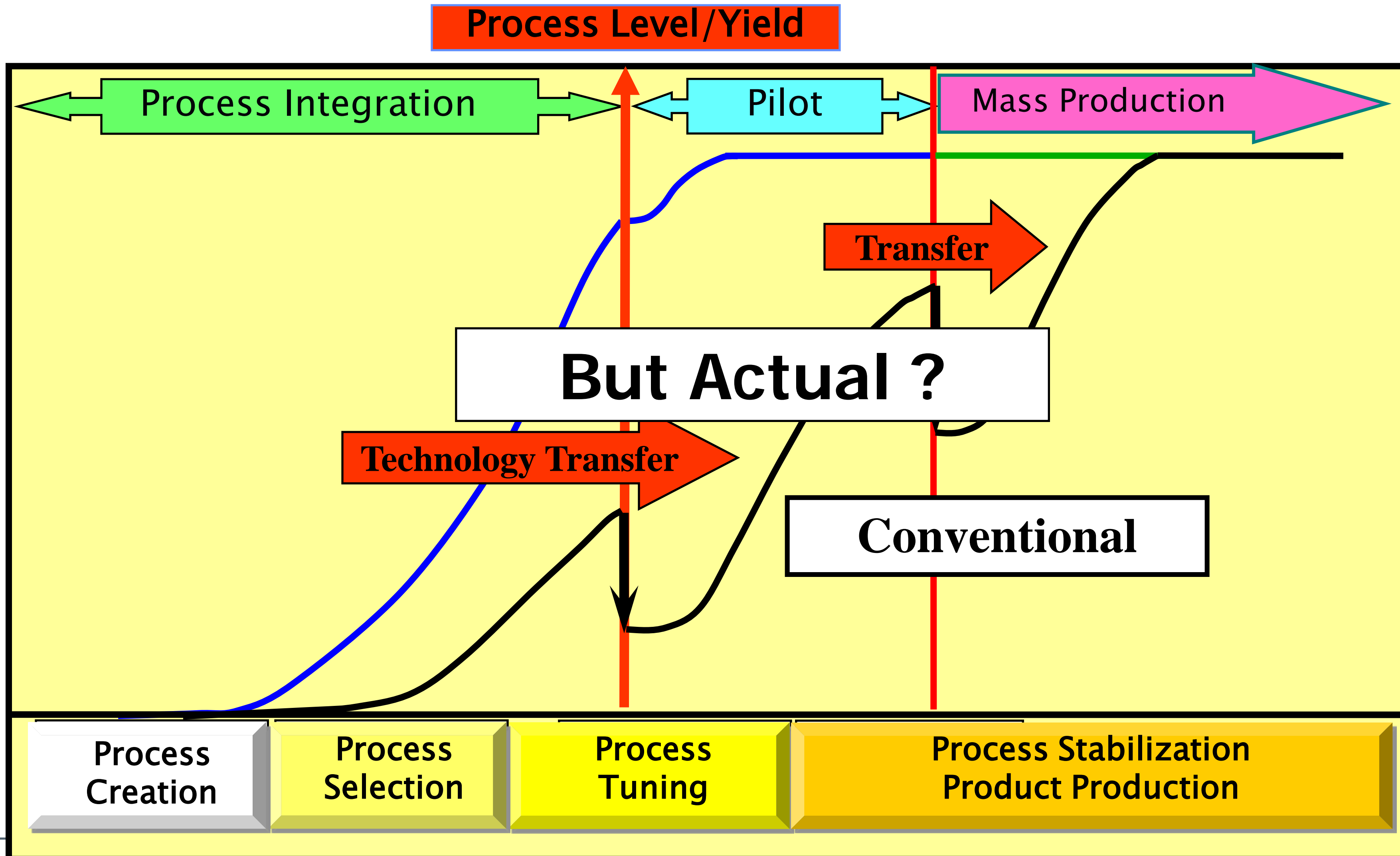
Metrology in Production



Micro- and Nano Electronics, following Moore's Law, require improvements in

- **Metrology**
- **Equipment**
- **Fab productivity**
- **Production costs**
- **Benigne manufacturing**

Actual Process and Yield Learning Curve



Source: Giichi Inoue,Toshiba Semiconductor

Typical Production Ramp Curve (Definition ITRS)

Production Ramp-Up Model and Technology Cycle Timing

Development
Production
100M
10M
1M
100K
10K
1K
200K
20K
2K
200
20
2
Volume (Parts/Month)
Volume (Wafers/Month)
Alpha Tool
Beta Tool
Production Tool
First Conf. Papers
First Two Companies Reaching Production
-24
-12
0
12
24
Months

Figure 2 A Typical Production "Ramp" Curve

450 mm Metrology Tools

Impact of 450 mm Wafer Diameter on Equipment and Metrology

Diameter	300 mm	450 mm
Thickness	775 µm	775 µm
Area	706 cm²	1589 cm²

Impacted Areas	Focus Items
Processes	uniformity of processes, contamination, thermal effects/uniformity, (cleaning, polishing, deposition, etch, anneal, ..)
Lithography	increase of area by 2.25 times requires high performance – high speed litho
Handling	deformation (→stress), transport issues, wafer translation (large distances, acceleration and settling times increase, vertical drift along the wafer)
Metrology	stages and handling, mapping capabilities, increase of area by 2.25 times requires high performance – high speed metrology (inspection), dimensional change due to thermal expansion coefficient, …
Data Management	amount of data, data quality, …

450 mm Metrology Tools

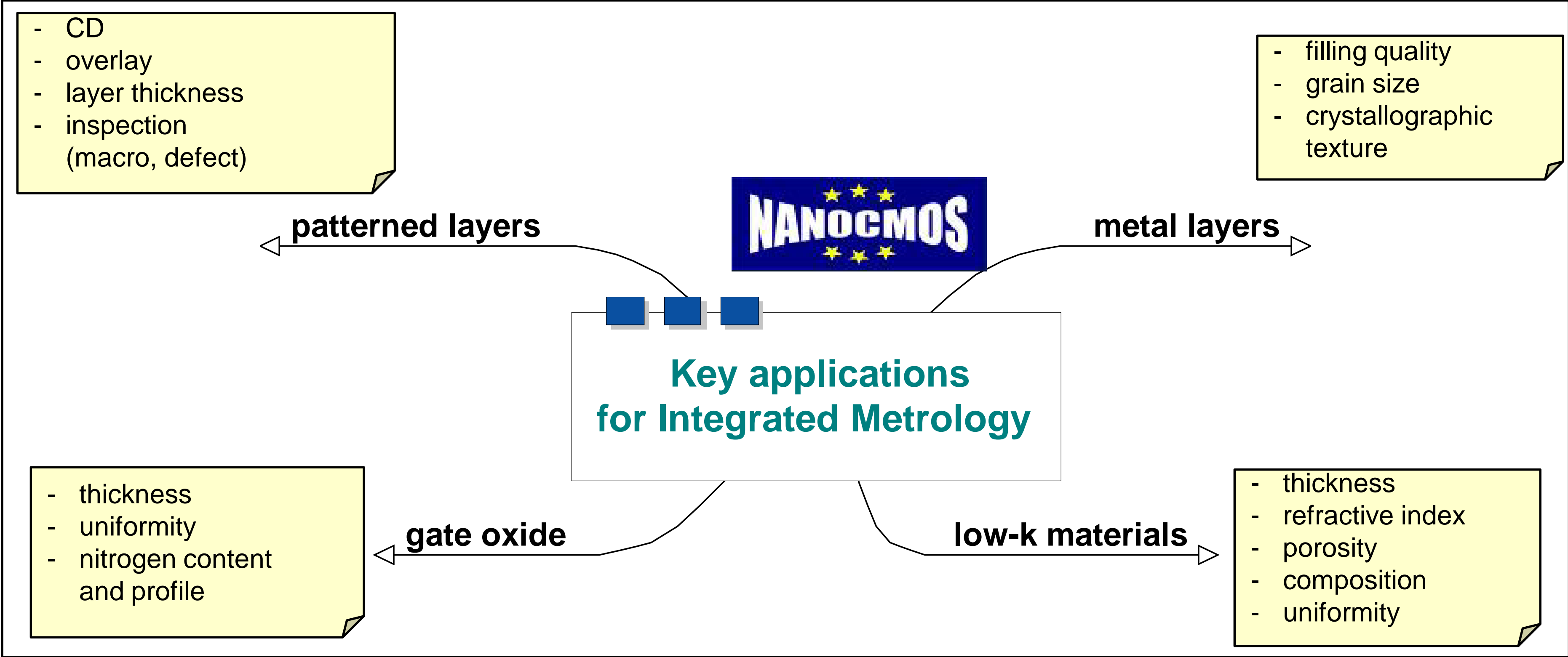
Potential Development Topics for 450mm Metrology Tools:

Stand-alone metrology	- Improved scatterometry (3D) - Particle measurement - Contamination monitoring - Stress measurement on nanoscale - Metrology tools for characterization of dielectrics, ultra-thin layers and interfaces (composition, morphology, geometric dimensions) - Reference materials
Data processing and algorithms	- Algorithms for the measurements of complex stacks and features - Models for the analysis of ultra-thin layers including interface and quantum effects - Data reduction algorithms for correlated sampling approach and calculation of quality data - Model for quantification of precision trade-off of IM to stand-alone metrology vs. improved sampling rate and time based information
Integrated metrology and sensors	- Sensors for improved equipment characterization and qualification - Sensors for characterization of plasma, litho, and CMP processes

450 mm Metrology Tools

Priorities in 450 mm

- to be defined by end-users (target specs, required improvements/modifications)
- may not differ from current ones, e.g. NANOCMOS



Contributions by IISB: Network in Metrology

www.semiconductors.co.uk

Optical Metrology

Equipment suppliers as users

Metrology is a European strenght!

BELFAST
DUBLIN
SALFORD
VTT
RENDSBURG
HAMBURG
LÜBECK
AMSTERDAM
NIJMEGEN
BERLIN
WITNEY OXFORDSHIRE
EINDHOVEN
DORTMUND
KREFELD
DRESDEN
LEUVEN
JENA
AACHEN
MAINZ
ERLANGEN
KARLSRUHE
PARIS
LANDSHUT
ST. FLORIAN
WIEN
MÜNCHEN
WIENER NEUSTADT
ZÜRICH
BUDAPEST
UNTERPREMSTÄTTEN
VILLACH
CROLLES
BERNIN
TRENTO
AGRATE
NOVARA
GRENOBLE
BOLOGNA
MILANO
TOULOUSE
ROUSSET
AVEZZANO
ROMA
PATRAS
ATHENS
AVEZZANO
MIGDAL HAEMEK
TEL AVIV
JERUSALEM

= supplier
= user
= R & D

Contributions by IISB

450mm Platforms for Metrology Development → Fraunhofer supported by LETI and IMEC ready to provide

- **Stand-alone metrology**: Realization of a 450 mm metrology platform, which enables the development of individual core metrology systems for 450 mm metrology requirements without the need to supply overhead wafer handling equipment, open automation, and fab data management.
- **Integrated metrology and sensors**: Realization of test beds to realize common standardized integration and automation strategies for the development of IM and sensors without the need to supply overhead automation, and fab data management.

R&D Activities for 450 mm Metrology → Fraunhofer ready to start

- IISB metrology and expertise applicable to 450 mm: wave front sensors, scatterometry, ellipsometry, digital imaging and processing, defect inspection, x-ray techniques
- equipment qualification/development: organic/inorganic contamination, thermo desorption, TXRF, vapor phase composition
- advanced sensor development for Stand-alone and integrated metrology
- virtual metrology and innovative APC concepts

Contributions by IISB

Support Activities for 450 mm Metrology Equipment Development

- preparation of test wafers and reference samples, e.g. with controlled deposition of contaminants and defects
- cleaning and polishing (double and single side)
- definition of standardized wafer for 450 mm wafer exchange amongst R&D sites using accepted specifications
- development of standards
- Set-up of distributed processing network including logistics for 450 mm

Summary & Outlook

- Metrology is the onset of the food chain
- Currently, appropriate modification of existing metrology tools is sufficient for starting 450 mm development
- support of equipment suppliers in the transition to 450 mm and towards novel metrology challenges
- 4 D metrology
- IISB will provide 450 mm atmospheric stage and 450 mm vacuum stage with (standardized?) sensor and metrology components accommodation
- Integration of metrology will be continued by IISB
- Global collaboration is mandatory in research and with industry
- Europe offers to share 450 mm development by a focus on 450 mm metrology

Thank you