



**PHILIPS**

Innovation  
Services

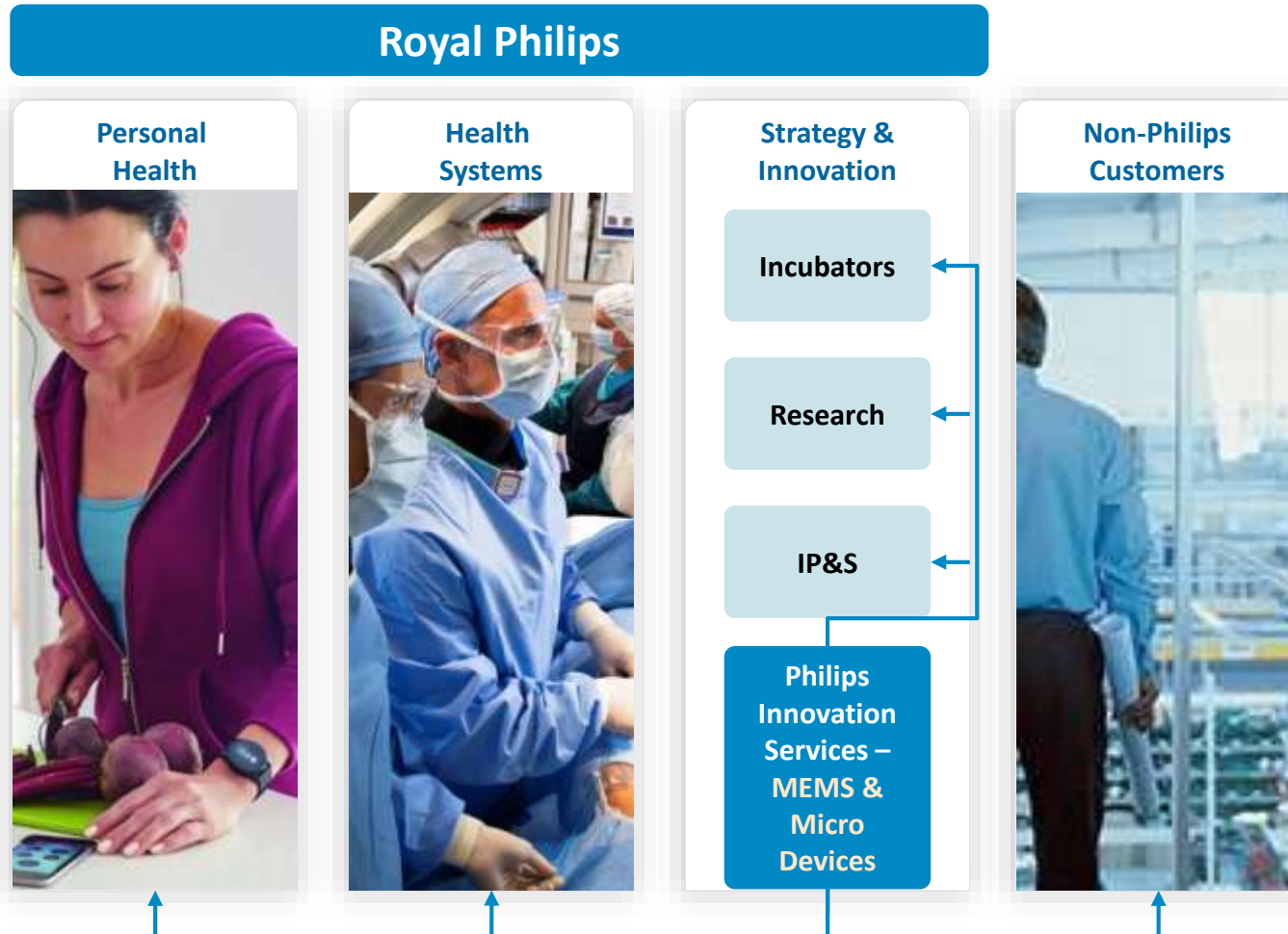
MEMS &  
Micro Devices

# Introduction to MEMS and Micro devices for Photonics

Robin de Bruijn & Andrzej Sielecki

October 3rd 2018

# Position in Philips



**PHILIPS**

Innovation  
Services

## A short introduction



Certified for

ISO  
**13485**

ISO  
9001

ISO  
14001



**Simple mission:**  
to accelerate  
your innovation

## Our **key areas** of **expertise**



**Medical devices  
& equipment**



**High-precision equipment**



**Connected digital products  
& systems**



**MEMS devices  
& micro-assembly**



**Manufacturing processes  
& systems**



**Design for reliability  
solutions**



**Industry consulting**



**Environment & safety**

# MEMS & Micro Devices

## *Process Development and Manufacturing*

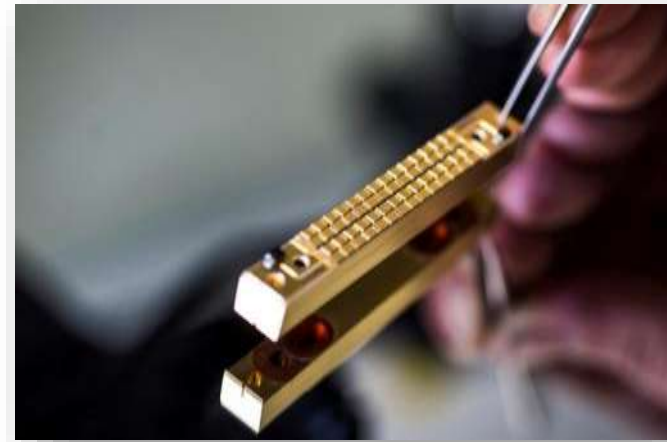
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MEMS & thin film products



Micro (Device) assembly & complex PCBA



2650 m<sup>2</sup>  
Cleanroom  
FTE: ~70



High Tech Campus, Eindhoven

2500 m<sup>2</sup>  
Factory +  
Cleanroom  
FTE: ~60



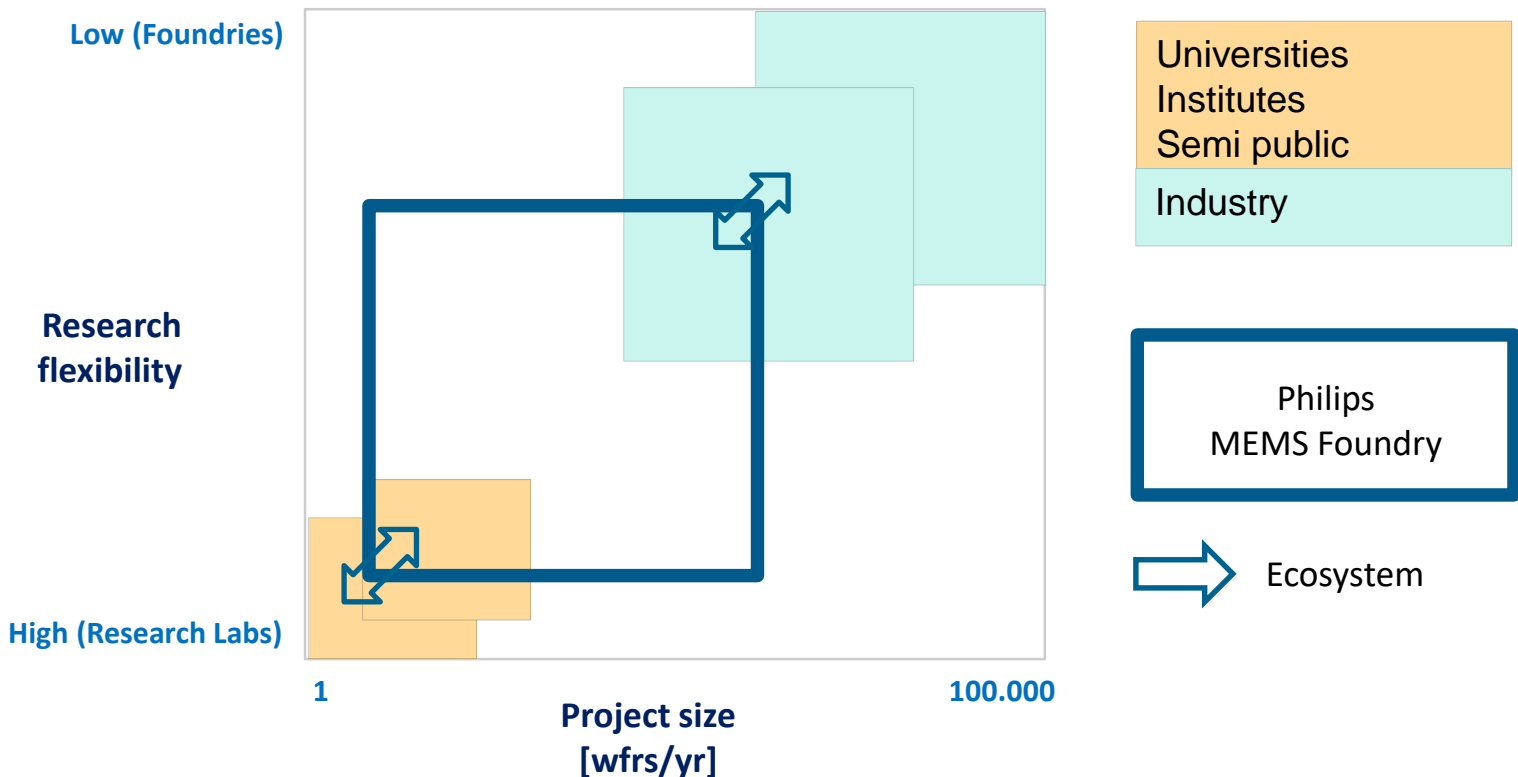
Strijp-S, Eindhoven

# Our position in the market

## *Filling and bridging the gap*

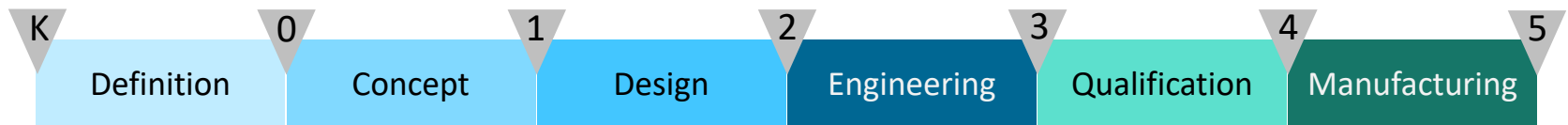
Filling: many MEMS applications stay below 5 wafers/year

Bridging: transfer to larger foundries for much higher volumes



# Our business model

- Our customers seek sustainable competitive advantage through custom-made components at limited investments and costs
- We provide process development and manufacturing services



- **Process development** — Time & material basis; General Terms & Conditions (GTC's)
- **Manufacturing services** — Fixed price basis; specifications, quality, quantities, supply conditions
- **Confidential information** — Well protected via NDA's and GTC's
- **Intellectual Property** — Ownership, field of use, licenses

# Photonic area's of current interest

Top 10 as established by PhotonicsNL and PhotonDelta:

1. Photovoltaics
2. Integrated photonics
3. Photonic detection
4. Photon generation technologies (lasers and light sources)
5. Optical materials (incl. thin films and coatings)
6. Optical sensors
7. Imaging technologies
8. Optomechatronics
9. Quantum (sensors and metrology)
10. Optical fibers



# Optical elements for photonics

## Customers

Leading companies in the domain of integrating optical functions into photonic devices

## Challenge

Process development and manufacturing of optical elements for applications ranging from infra-red (IR) through extreme ultra-violet (EUV)

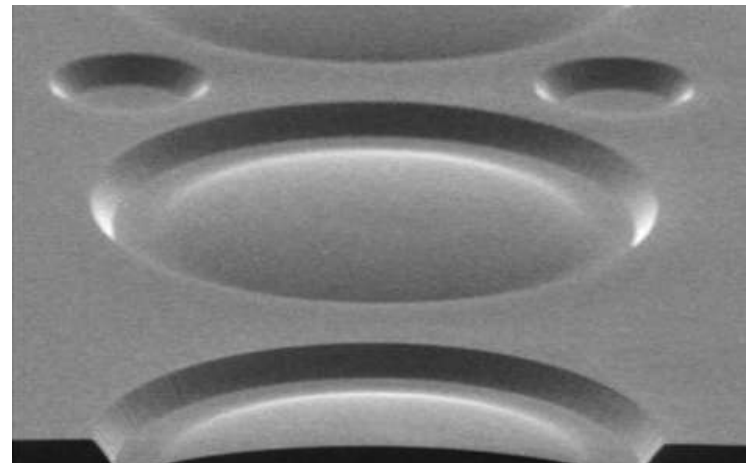
## Key Results

Many concepts proven, some taken into production and market

## Business benefit

Integrated optical elements increase value of photonic devices

- Optical coatings (anti-reflection, mirrors, filters)
- Gratings for
  - light outcoupling from solid state lasers
  - (F)IR sensors like spectrometers
- Spectral filters based on nm thick membranes
- Photonic crystals (various metals and dimensions)
- Silicon waveguides
- Alignment markers on various substrates
- Silicon Fresnel lenses (IR)
- Silicon and GaAs based microlenses (IR, UV)





# Substrate-Conformal Imprint Lithography (SCIL)

Advanced lithography for unique process flows

## Customer

Leading OEM in solar equipment market

## Challenge

Develop SCIL-based process flow and manufacture custom-designed substrates with structured noble metal with feature size below 200nm

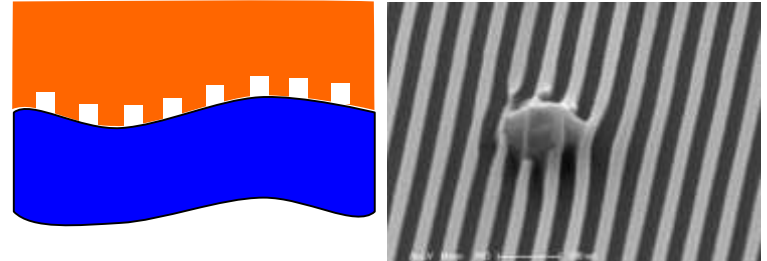
## Key Results

Regular flow of nano-patterned wafers according to customer specification

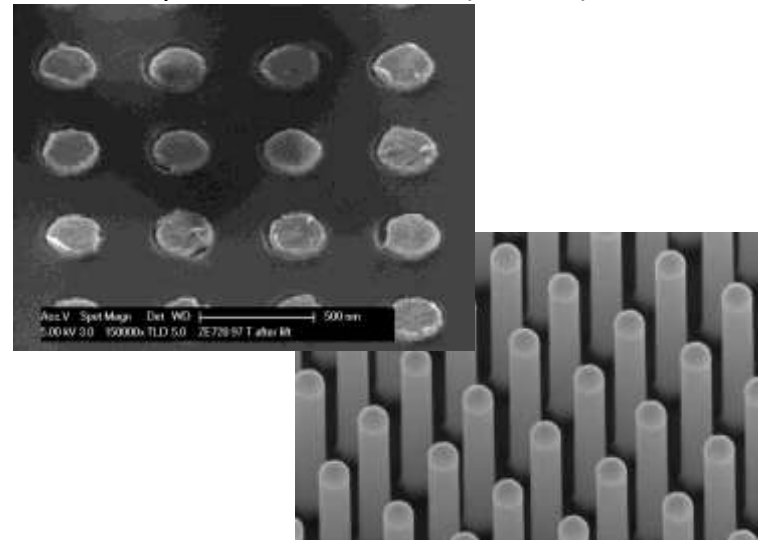
## Business benefit

Boost in efficiency of R&D of process and equipment development

Soft rubber stamp and imprint

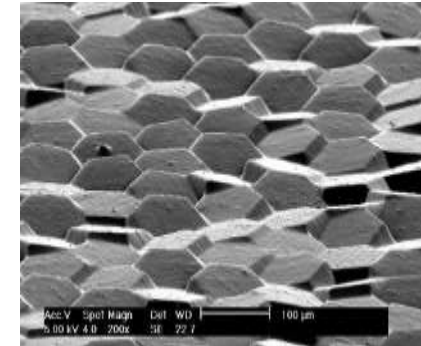
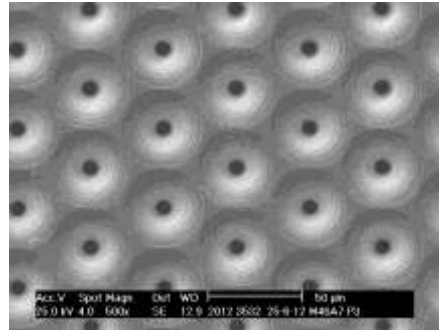
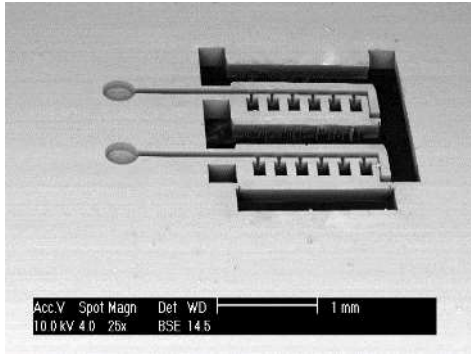


Nano templates with Au dots (200nm)

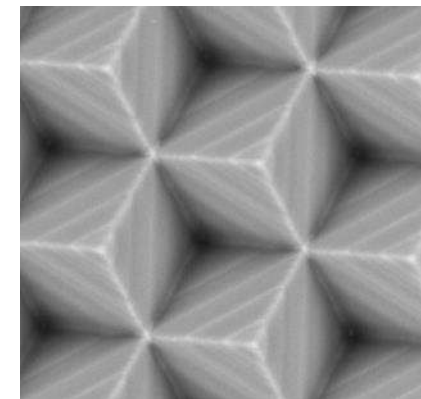
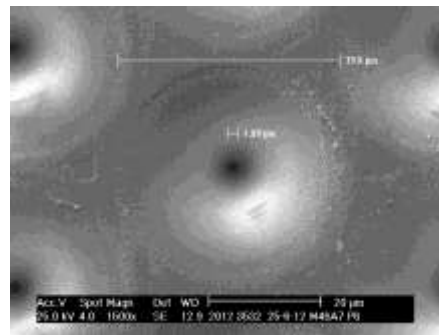
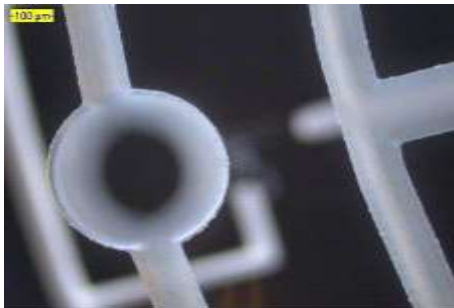


Nano wires made by customer

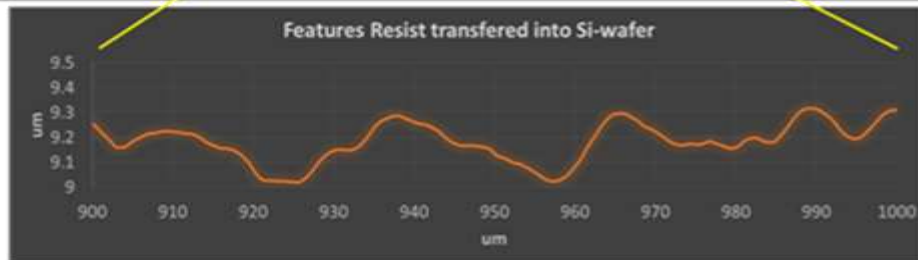
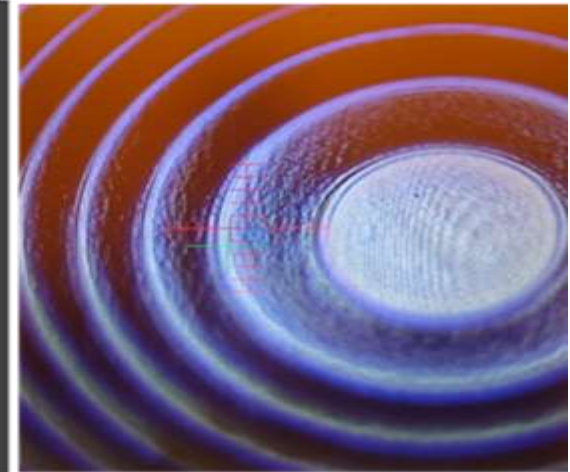
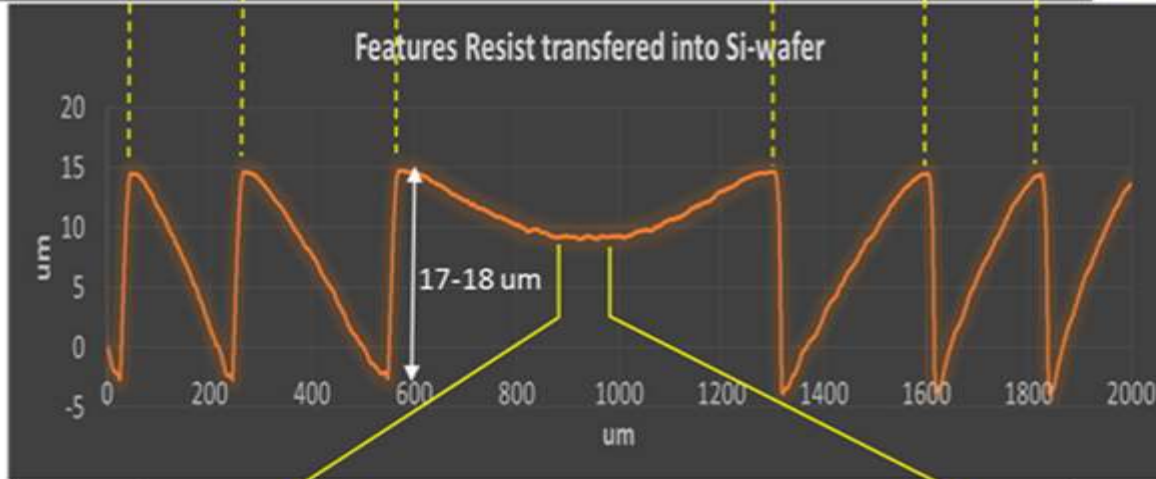
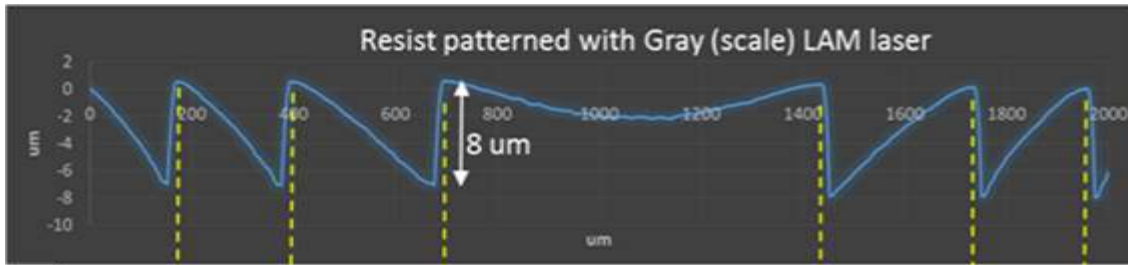
# Examples: laser prototyping/masters



*From  $\mu$ -fluidics to sieves to non-imaging optics*



# Example: Greyscale Resist Ablation



# Electronic/Photonic Micro assembly

## Customers

Leading companies, ventures and start-ups in the domain of integrating optical functions into devices.

## Challenge

Prototyping, Process development and Manufacturing of sub-assemblies for applications ranging from medical in-body devices to IR heater modules.

## Key Results

Many concepts proven, some taken into production and market

## Business benefit

Integrated optical elements increase value of photonic devices

## Examples

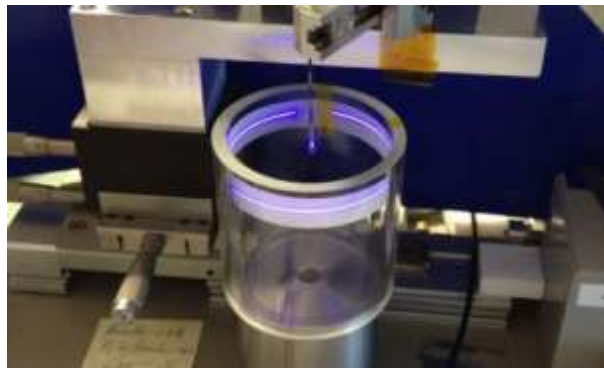
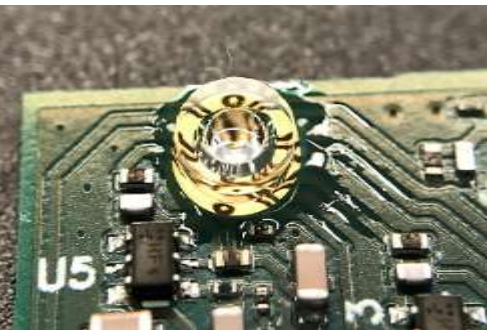
- Probes for spectral sensing
- Shape sensing devices
- IR Heater Modules
- Sensors for particle detection
- Optical Interrogator Modules
- Illumination Devices



# Examples of Assembly Services

Prototyping and manufacturing for Photonic Device (Sub-)Assemblies:

- Optical Sensors
- Illumination Modules



# Pleased to meet you



**develop the  
product and  
process**

creative  
out-of-the-box  
solutions for the  
'seemingly'  
impossible



**Unmatched  
flexibility  
in materials, metals  
and polymers**

on different  
substrates and  
various shapes  
using over 100  
state-of-the-art  
tools



**End-to-end**

many back-end  
& integration  
services  
speeding up  
your time to  
market

**Certified for**

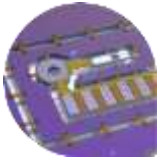


for medical  
applications, we  
develop your  
process and  
manufacture  
under ISO 13485



# MEMS & Micro Devices services

## MEMS foundry services



**MEMS proof-of-concept ›**



**Thin film processing ›**



**MEMS process development ›**



**MEMS back-end services ›**



**MEMS manufacturing ›**

## Micro devices facility services



**Industrial PCBA prototyping ›**



**Assembly of high-end PCBA's ›**



**Interconnect architecture & prototyping ›**

## Foundry facts

- 2650 m<sup>2</sup> state-of-the-art cleanroom of class 100 – 10.000
- Large set of 150mm and 200mm high-end tools
- Flexibility to work with materials ranging from Ag to Zn, including 'CMOS-forbidden' materials, alloys, dielectrics and polymers like Parylene
- Flexibility to work with substrates: Si, III/V, glass, square and round, up to 8"

### More information:

[www.innovationservices.philips.com/mems](http://www.innovationservices.philips.com/mems)



**PHILIPS**

Innovation  
Services

MEMS &  
Micro Devices



How can we help you  
create sustainable  
competitive advantage  
through custom MEMS  
devices?





# What our customers value

- DD The **flexibility** in working together
- DD Our **responsiveness** to change requests
- DD Our ability to provide **creative out-of-the-box solutions** for the ‘seemingly impossible’ – a capability developed from working with **Philips Research** for 40 years
- DD Manufacturing MEMS devices under **ISO 13485** and 9001



**We can do it all with one partner ›**

Océ-Technologies



**Building a competitive light sensor ›**

Elesta



**Very flexible to meet specific requirements ›**

Sol Voltaics



**Enormous diversity of skill set ›**

Philips Health Systems

# Proud to serve...

**PHILIPS**



More information at <https://www.innovationservices.philips.com/looking-expertise/mems-micro-devices/>

# MEMS Foundry facts

- Cleanroom 2650 m<sup>2</sup>, class 100 – 10000
- Industrial 200 mm production equipment
  - Large installed base 100+ systems
- Flexibility to work with materials ranging from Ag to Zn, W and Ru, including 'CMOS-forbidden' materials, alloys, dielectrics, and polymers like SU8, BCB, Polyimide, Parylene
- Flexibility to work with a variety of substrates:
  - Si, III/V, glass; up to 8"
- Installed capacity is ~25 k 150mm wafers/year
- 2 shift operation
- Yearly investments in new capabilities
- Quality systems: ISO9001, ISO13485, ISO14001



# MEMS Foundry facts

## Summary of capabilities (#1/2)

- Etching
  - Dry
    - SPTS cluster tools including Bosch process
    - Ion Beam Etcher
  - Wet
    - Variety of etch baths and chemicals
- Deposition
  - Evaporation
  - PECVD: oxide, nitride, Si
  - Sputtering
  - LPCVD: Si, TEOS, Nitride
  - ALD: Al<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub>, HfO<sub>2</sub>
  - Parylene coating
  - Laminator



# MEMS Foundry facts

## Summary of capabilities (#2/2)

- Lithography
  - Mask aligner (including SCIL)
  - I-line stepper
- Wafer bonding
  - Adhesive bonding
  - Fusion bonding
  - Anodic bonding
  - Thermo-compression bonding
- CMP
- Metrology
  - Optical
  - Surface profiler
  - Defectivity inspection
  - SEM
  - Reflectometry, Ellipsometry
  - Automated probe station



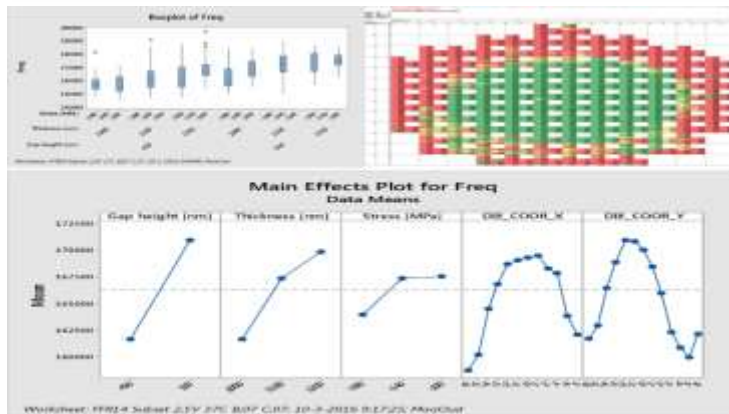
# Process development

## Phase Gated Approach

### MPD: Manufacturing Process Development



## DoE



## Progress review

Project: **Memphis FFR** Number: X24-1P-0001 Segment: CRM: Rob Wendrich Reporting date: 07-apr-2016  
 Prj. Mgr.: Frank Agricola Class: A Prime Contractor IGT-BI

**Results** (Info/Comm. Organization) (Time Money Quality) (Prod. cost/supply)

**Deliverables** (weeknumbers, line is planned, bar is actual)

**Top 4 Achievements**

- Excellent performance of V2 design: ASIC under membranes
- Saline breakdown problem solved with Masterbond coating
- Dirt performance well within 2 mmHg specification
- Stress sensitivity at bending test solved by V2 and PIM

**Top 4 Issues**

- Collapse behaviour on ASICs not stable. No collapse on first MPS wafers

**Top 4 Risks**

- No process solution for uncontrolled collapse
- Design solution for collapse does not work
- Design solution for collapse has negative effect on product performance

**Top 4 Next targets**

- Try out new membrane anchor design, V4 (INT overlapping INS)
- Find process root cause for poor performance MPS03 (first ASIC MPS lot)
- Update planning and financial picture with IGT-BI
- Implement production testing infrastructure

**Milestones**

PPC / Proj.Acc. / G0	Planned original	Planned update	Actual
RvF / G1 / DC&ES	01-oct-2015	15-oct-2015	15-oct-2015
Ev / G2 design fr.	01-dec-2015	20-mei-2016	11+19 dec-2015
OS process freeze	01-mei-2016	20-jul-2016	
RIL / G4 / EC	01-mei-2016	03-jun-2016	
OS Volume Release	15-aug-2016	23-oct-2016	
	n/a	n/a	

**Product Creation Process**

Development (Concept phase, Design phase, Engineering phase)

## pFMEA

**Process Failure Mode & Effect Analysis**

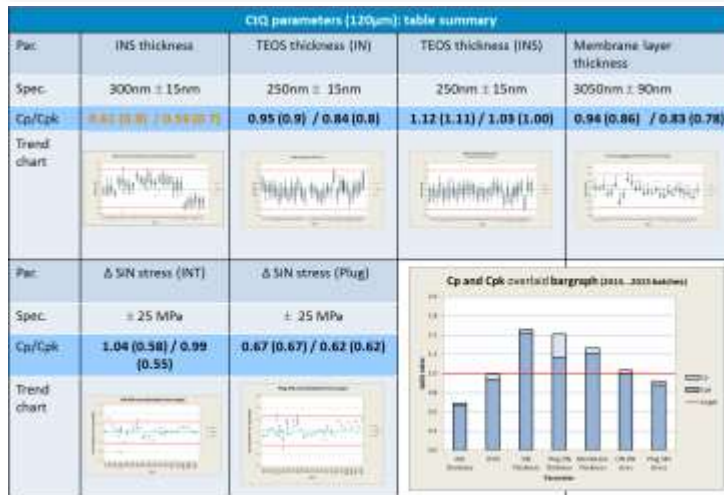
Design: RES Responsible: Mark Voronobch, Harald Rosen, Gausp, Nematpour, Jari Ten, Yues, Pengy

Facilitator: Mark Voronobch

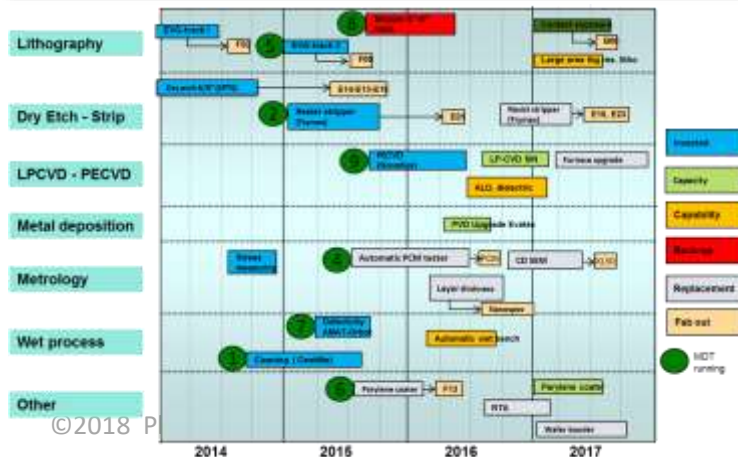
Process step	Potential failure mode	Potential effects of failure	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control
Process step 1	Potential failure mode	Potential effects of failure	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control
Process step 2	Potential failure mode	Potential effects of failure	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control
Process step 3	Potential failure mode	Potential effects of failure	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control
Process step 4	Potential failure mode	Potential effects of failure	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control
Process step 5	Potential failure mode	Potential effects of failure	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control
Process step 6	Potential failure mode	Potential effects of failure	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control
Process step 7	Potential failure mode	Potential effects of failure	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control
Process step 8	Potential failure mode	Potential effects of failure	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control
Process step 9	Potential failure mode	Potential effects of failure	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control
Process step 10	Potential failure mode	Potential effects of failure	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control	Prevention	Detection	Control

# Process control, defects, yield, capex investment

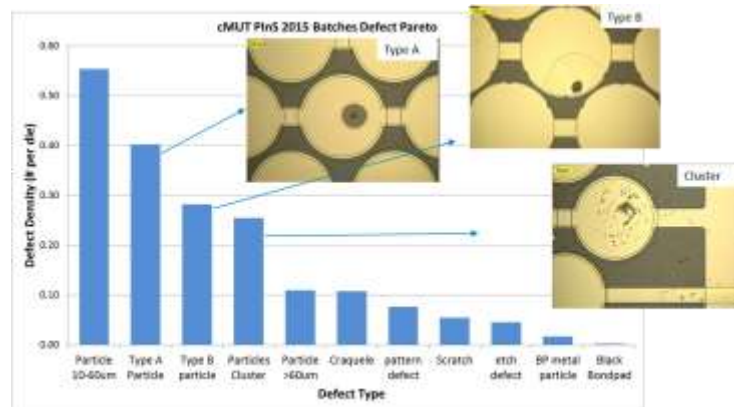
## Process control



## Capex investment



## Defectivity

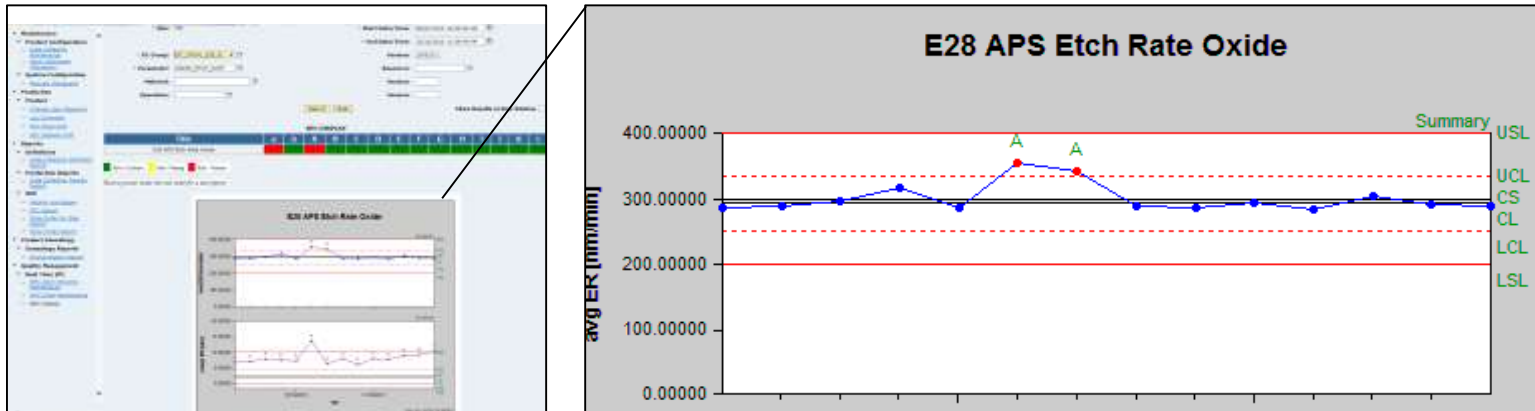


## Yield





# MES: vehicle for quality

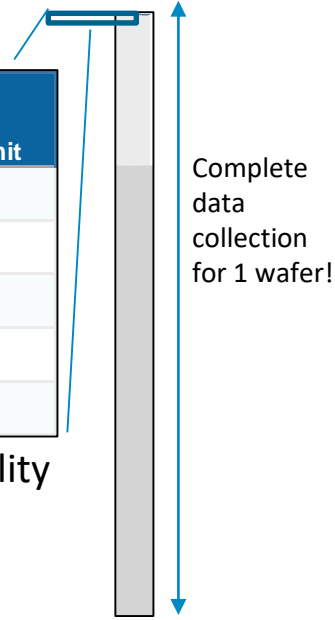


Example of SPC implementation in MES

- Full traceability on every wafer in the cleanroom
- Full traceability on all measurements
- Waiver implemented for oos measurements

Value	Unit of measure	Low Limit	High Limit
3.32	µm	-20	20
3.32	µm	-20	20
-532.194	m	-4000	4000
-532.194	m	-4000	4000
-1.37	µm	-20	20

Example of Data collection and traceability



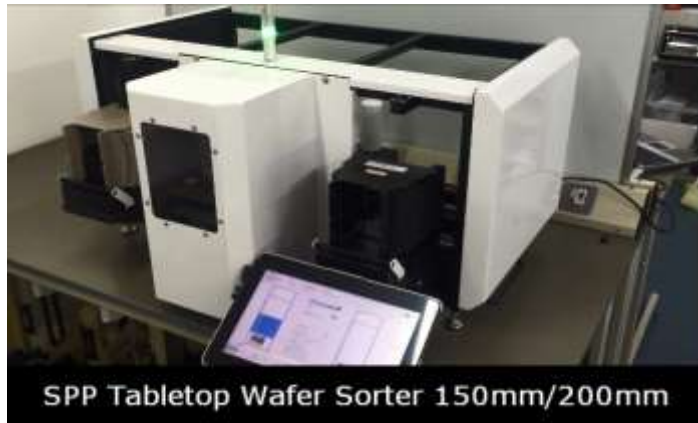
# Main equipment and capacity

+/- 5MEUR yearly investments for the MEMS Foundry

Equipment	Number of tools	Wafers size (inch)	# wafers/tool/hr
Dry Etching (SPTS- APS/ICP/Pegasus)	2	6 and 8	1-25
Litho (ASML stepper)	2	6 and 8	10-40
Exposure (EVG track)	2	6 and 8	10-25
Coat-Develop (Novellus)	2	6 and 8	10 - 50
PVD (Veeco 5 chambers)	2	6 and 8	10-30
Resist strip (Trymax)	1	6 and 8	25- 50
LPCVD (Tempress)	1	6 and 8	25-50
ALD (ASM)	1	6 or 8	1 - 25

# Recent investments

Wafer sorter/reader



Wafer stepper



Inspection system



PCM tester



# Upcoming investments

4 chamber wafer bonder



Polyimide track



Wet Bench



SEM

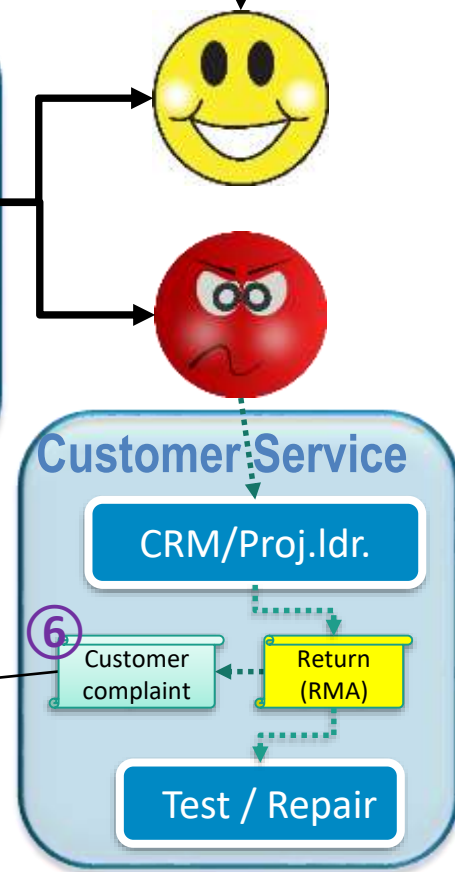
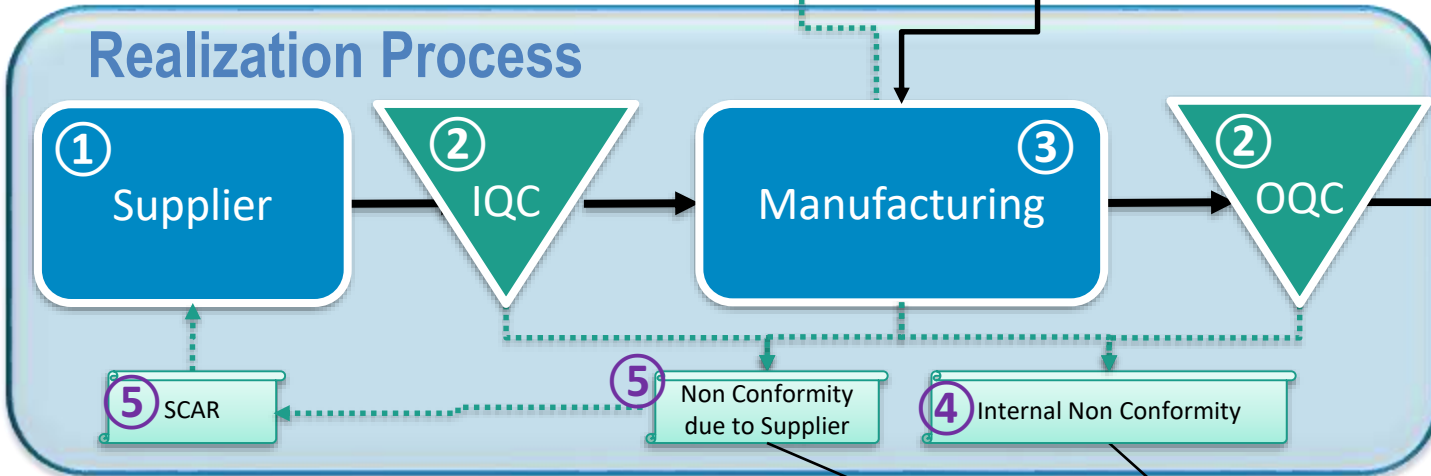
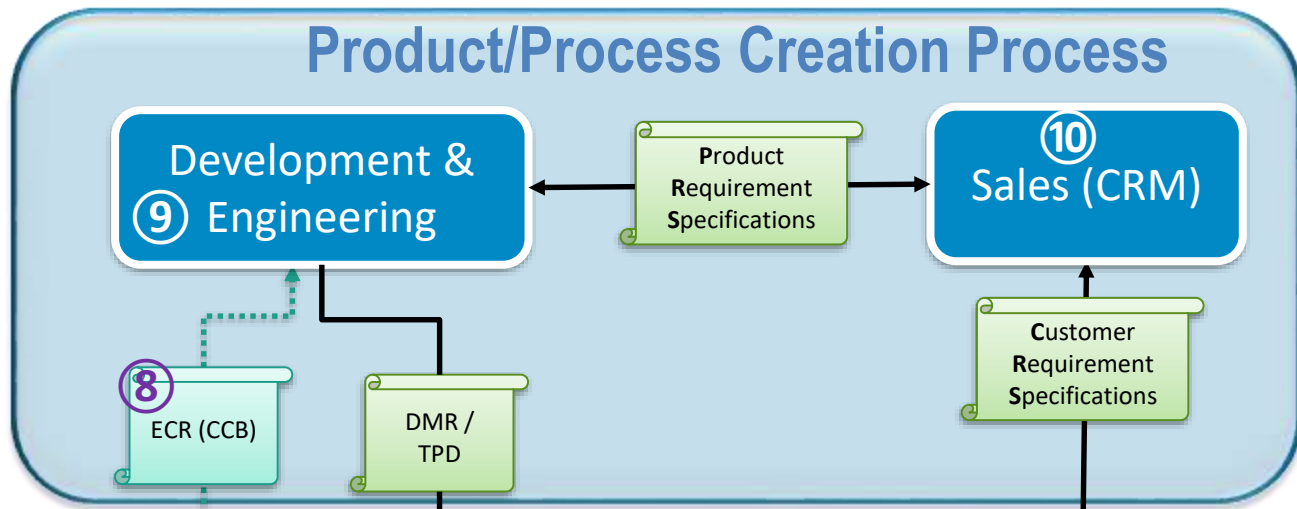


# Quality organization

- Certified ISO9001:2015, ISO14001, ISO13485:2003
- Covering (~8FTE)
  - Quality Assurance
  - Development Quality
  - Manufacturing Quality
  - Supplier Quality
- Quality Management System (MSIS) and Training Program
- Quality Review Board
- Change Control Board
- Internal and Customer Audits
- KPIs (COPQ, Customer Complaints, Supplier Quality)

# Quality Landscape

**12**  
Quality Management System: TL way of working: procedures, forms, templates



**11** Customer audits & Internal audits

**7** Product quality review board

- Legenda:**  
 CCB: Change Control Board  
 CRM: Customer Relations Manager  
 DMR: Device Master Record  
 ECR: Engineering Change Request  
 IQC: Incoming Quality Control  
 OQC: Outgoing Quality Control  
 RMA: Return Material Authorization  
 SCAR: Supplier Corrective Action Request  
 TPD: Technical Product Documentation