Introduction to MEMS and Micro devices for Photonics

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Position in Philips

Royal Philips

- Personal Health
- Health Systems
- Strategy & Innovation
  - Incubators
  - Research
  - IP&S
  - Philips Innovation Services – MEMS & Micro Devices
- Non-Philips Customers
A short introduction

Development, realization & consultancy
(inside & outside Philips)

~1,000 experts

10,000 m² infrastructure
test & prototyping facilities, cleanrooms, labs

Globally operating

NPS >50%
Customer satisfaction of 4.5/5

Certified for
ISO 13485
ISO 9001
ISO 14001

Simple mission: to accelerate your innovation

End-to-end

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

MEMS & thin film products

Micro (Device) assembly & complex PCBA

2650 m²
Cleanroom
FTE: ~70

High Tech Campus, Eindhoven

2500 m²
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 μ-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

creative out-of-the-box solutions for the ‘seemingly’ impossible

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

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

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

Certified for

ISO 13485
MEMS & Micro Devices services

MEMS foundry services

- MEMS proof-of-concept
- MEMS process development
- MEMS manufacturing
- Thin film processing
- MEMS back-end services

Foundry facts

- 2650 m² 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”

Micro devices facility services

- Industrial PCBA prototyping
- Assembly of high-end PCBA’s
- Interconnect architecture & prototyping

More information:
www.innovationservices.philips.com/mems
How can we help you create sustainable competitive advantage through custom MEMS devices?
What our customers value

The **flexibility** in working together

Our **responsiveness** to change requests

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

Manufacturing MEMS devices under **ISO 13485** and 9001

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**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...

MEMS Foundry facts

- Cleanroom 2650 m², 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: Al2O3, SiO2, HfO2
  – 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

Top 4 Achievements
- Excellent performance of V2 design: ASIC under membranes
- Solve breakdown problem soiled with Masterbond coating
- Cell performance well within 2-meeting specification
- Stress sensitivity at bending test solved by V2 and PIM

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
- Previous session overestimated in terms of cleaning impact

Top 4 Issues
- Collapse behaviour on ASICs not stable. No collapse on first MPS wafers
- Clean process root cause for poor performance: MP500 (last ASIC MP5 lot)
- Update planning and financial pictures with ICT B1
- Implement production testing infrastructure

Product Creation Process

pFMEA

Process Failure Mode & Effect Analysis

<table>
<thead>
<tr>
<th>Design</th>
<th>Process Failure Mode &amp; Effect Analysis</th>
<th>Products</th>
<th>Failure Mode</th>
<th>Effect</th>
<th>Likelihood</th>
<th>Consequence</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Current cause of performance defect MP500</td>
<td>ASIC MP5</td>
<td>2015-01-01</td>
<td>MP500 (last ASIC MP5 lot)</td>
<td>Failed</td>
<td>High Likelihood</td>
<td>Implementation of engineering change and testing</td>
</tr>
</tbody>
</table>
Process control, defects, yield, capex investment

**Process control**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>INS thickness</td>
<td>300nm ± 15nm</td>
</tr>
<tr>
<td>TEOS thickness (IN)</td>
<td>250nm ± 15nm</td>
</tr>
<tr>
<td>TEOS thickness (INS)</td>
<td>250nm ± 15nm</td>
</tr>
<tr>
<td>Membrane layer thickness</td>
<td>350nm ± 15nm</td>
</tr>
</tbody>
</table>

**Defectivity**

- Type A
- Type B

**Capex investment**

**Yield**

- Lithography
- Dry Etch - Strip
- LPCVD - PECVD
- Metal deposition
- Metrology
- Wet process
- Other

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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

Example of Data collection and traceability
Main equipment and capacity
+/- 5MEUR yearly investments for the MEMS Foundry

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

- Wafer sorter/reader
- Inspection system
- Wafer stepper
- PCM tester
Upcoming investments

4 chamber wafer bonder

Polyimide track

Wet Bench

SEM
Quality organization

- 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

1. Supplier
2. IQC
3. Manufacturing
4. Internal Non Conformity
5. SCAR
6. Non Conformity due to Supplier
7. Customer audits & Internal audits
8. DMR / TPD
9. ECR (CCB)
10. Sales (CRM)
11. 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