Comprehensive Foundry Services from a High-Volume MEMS Manufacturer

Outline

- Part I - MEMS at Bosch and Foundry History
- Part II - Why Foundry Business?
- Part III - Product Development using Foundry Services
- Part IV - Factors Creating Customer Satisfaction
- Part V - The German Europractice Manufacturing Cluster
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MEMS at Bosch and Foundry History

... one of the leading MEMS-manufacturers worldwide
Milestones MEMS at Bosch

- 1987: Start of MEMS research activities
- 1989: Development section for MEMS
- 1992: Deep trench process developed (the “Bosch Process”)
- 1993: First volume MEMS-product: Pressure sensor
- 1995: SOP micromachined mass flow sensor
- 1997: SOP micromachined accelerometer
- 1997: Start of component sales to external customers
- 1998: Silicon gyro in mass production
- 1999: Research Center Palo Alto founded
- 2002: Market introduction of 2nd generation accelerometers
- 2002: More than 70 Mio MEMS-based sensors per year
- coming: Hydrogen sensor, gas sensor, new applications ...

Bosch Foundry Highlights

- 1995: Release of Si surface micromachining design rules
- 1996: 1st MPW run with 10 customers
- 2000: 1st low volume production
- 2001: 1st single customer wafers
- 2002: Start of bulk micromachining foundry activities targeting at life science applications;
  Release of bulk micromachining process catalog
- 2003: 1st bulk micromachined biotech chips
MEMS at Bosch and Foundry History

IC/MEMS-Fab in Reutlingen
- 4000 m² CMOS-Fab, MEMS-Frontend processing
- 3000 m² MEMS-Backend fab
- Test center
- Assembly lines for packaged MEMS-products
- MEMS-Output in 2002: ~70 Mio Devices
- Maximum capacity: 1500 wafer starts/day
- ISO9000, QS9000 qualified
- 200+ engineers in development

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Why Foundry Business?
- Initially AE purely captive MEMS supplier
- Foundry service
  - helped to make known Bosch MEMS activities
  - provided confidence in Bosch microsystem technology
  - raised interest in the traditional Bosch market (automotive) as well as in non-automotive markets (consumer electronics, industrial goods, bio-/medical market)
  - broadened the customer base and lead to new product developments for the external market

Foundry Business from a High-Volume Manufacturer’s Perspective

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Product Development

Customer's Product manufactured by Bosch

Standard Sensor (Bosch)

MST-Element (Bosch)

Customer's Layout

Design (Bosch Design House)

Customer's Idea = Customer's IP

Development time and costs depending on starting level

Product Overview Inertial Sensors

Airbag accelerometer

Peripheral acceleration sensor

Angular rate sensor: navigation and roll over
**MPW Concept for Surface Micromachining**

**CUSTOMER**

- **Design**
- **Chip**
- **Evaluation**

**Design Rules**

<table>
<thead>
<tr>
<th>Rule</th>
<th>Description</th>
<th>Dimension</th>
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<tbody>
<tr>
<td>V01</td>
<td>Wafers</td>
<td>6.75 ± 0.15</td>
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<tr>
<td>V02</td>
<td>Passivation</td>
<td>3.5 ± 0.15</td>
</tr>
<tr>
<td>V03</td>
<td>BURIED POLYSILICON</td>
<td>0.45 ± 0.05</td>
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<tr>
<td>V04</td>
<td>SACRIFICIAL OXIDE</td>
<td>1.8 ± 0.2</td>
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<tr>
<td>V05</td>
<td>EPITAXIALLY GROWN POLYSILICON</td>
<td>10.3 ± 1.0</td>
</tr>
<tr>
<td>V06</td>
<td>METALLIZATION</td>
<td>1.3 ± 0.2</td>
</tr>
<tr>
<td>V07</td>
<td>CAP Wafer</td>
<td>380 ± 15</td>
</tr>
<tr>
<td>V08</td>
<td>Cavern</td>
<td>75 ± 25</td>
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</tbody>
</table>

- **Multi Project Wafer**
- **Volume Production**

**Shared costs during development, prototyping and low volume production**

Detailed design-rules available free of charge upon signature of NDA
MPW-Runs

- Up to 16 customers share one wafer
- 3 runs per year
- Run 22 underway
- Turnaround time ~14 weeks
- so far more than 80 projects and 200 designs
- Start next run: December 2003
- Contact:

  Dr. Wilhelm Frey/Dr. Christoph Gahn
  europractice_foundry@de.bosch.com
  www.europractice.bosch.com

Case Study: Gyro DAVED-RR by HSG-IMIT

Properties
- Resolution 0.01°/s
- Range 200°/s
- Dimension 2.3*2.6 mm²

Applications
- Navigation systems
- Camera stabilisation
- Robotics
The Product DAVED-RR®

- Product development focused to the field of automated guided vehicle system (driverless vehicles) in low and mid-range volume
- Sensor is used to assist or replace the fibre optic gyroscopes (low performance class)

etp - electronics trading & production (Freiburg)
  - Assembly, Packaging and Final Test of the Sensor
  - Sales and Marketing

Hahn-Schickard-Gesellschaft
Institut für Mikro- und Informationstechnik – www.hsg-imit.de

Inertial Sensors Systems

Product Development using Foundry Services

Approach to Bulk Micromachining Foundry

- Extend foundry service to Silicon-bulk-micromachining technology
- Target applications: Life Sciences
- Bosch USP: - experience with high volume production of MEMS
  - large technology portfolio
- Feasibility studies concerning high volume production of devices
- Prototyping for selected projects
- Definition of a standard foundry MPW process for life science applications
**Current Status**

- Standard process modules are defined (e.g. etching, lithography, bonding, porous silicon, CMP, ...)
- Process module catalog available upon signature of NDA
- Discussions with potential customers (on-going)
- Feasibility studies for 10 projects
- Prototyping for 4 customers

**Possible Devices**

- Pumps
- Valves
- Microchannels
- Mixers
- Dispensers
- DNA arrays
Customer Project: Axaron, Heidelberg

“Three-dimensional DNA Array” BBC

- Low fluorescence signal from Si-substrate
- Advanced fluidic functionality by using capillary effects
- Opportunity for convenient CCD readout

Parallel Dispensing Head matching the BBC

Cross section of a single nozzle:
Through hole in wafer is fabricated using three high rate ASE steps
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Factors Creating Customer Satisfaction

- Reliable Stable Process
  - MPW uses same process as >100M Bosch MEMS since 1996
  - Bulk foundry relies on well-proven process steps:
    >150M pressure and air-flow sensors since 1993
- Comprehensive Design Support
  - Dedicated Tools by MEMSCAP and IntelliSense
  - Design house service by AML and FhG-ISIT
  - DRC, chip templates, individual support
- Punctuality and Regularly Scheduled Runs
  - Three MPW runs per year since 1996
  - Information: process details, packaging know-how, reliability ...
- Special Services: packaging, better vacuum, wafer mapping ...
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A Microsystems Manufacturing Cluster for European Users – AMICUS

Fraunhofer Institute for Si Technology
- Greytone-lithography
- Metal surface micromachining
- Design house service
- Micromirrors
- Microlenses
- Diffractive optical elements
- Microswitches

Robert Bosch GmbH
- Si surface micromachining foundry
- Si bulk micromachining foundry
  - Accelerometers
  - Tilt sensors
  - Gyrosopes
  - Microfluidic chips, BioMEMS

HL-Planartechnik GmbH
- Thin film technology
- Silicon membrane technology
  - Thermopiles
  - Temperature sensors
  - Magnetoresistive sensors