Introduction

• Microsys Description
• Microsys Expertise
• Technology Portfolio
• Facility and equipment
• Microsys Research projects overview
• Bio-sensor for bio-molecules detection (DNASip project)
• MICROSYS is a laboratory of the University of Liege (part of EMMI) created in 2006
• Main research fields:
  – Energy harvesting and scavenger system
  – Microsystem in harsh environment and Bio/Organic chip encapsulation
  – Autonomous micro system
• 9 projects: 5 ERDF (European Regional Development Fund) funding, 4 industrial (Walloon Region funding) → total budget of 4 millions €
• Team: 1 Professor, 3 senior researcher, 4 research engineers, 1 technicians, 1 PhD student
• 1 spin-off company: TAIPRO Engineering (created in 2009), the commercial answer of Microsys for packaging and microsystem engineering service for industrial needs
Microsys Expertise

4 core competences of Microsys lab

- Design and development state-of-art microsystems
- Multiphysics modeling & simulation (incl. thermal mechanical)
- Edge-cut micro-assembly, interconnect and packaging technology
- Test and characterization
Packaging and integration

Biochip encapsulation

Stacking

Système in Package

Application on glass

Microsystem packaged

For high temperature

Flexible electronic

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Facilities

- 200 m² certified clean room class 10,000 (ISO7)
- 4 separate rooms (2 for packaging, 1 bio, 1 chemical)
- Fully ESD equipped infrastructure (rooms, furniture, clothes etc)
Equipement
Industrial Projects

- **Techspace Aero (HM+)**: Microsystem for health monitoring of aircraft engine lubrication system.
- **Sonaca (HM+)**: Microsystem for health monitoring of moving wing parts
- **CMI (MINT)**: Microsystem for identification and control of bearings lubrication on heavy industrial line.
- **Tecnolub (Micro Lub)**: Microsystem for the monitoring of a microlubrication system on CNC equipments
- **GreenCom Development (Green+)**: development of a double flux heat scavenging system for existing buildings.
- **CorisBio (DNASip)**: Integration of protein grafted chip in microfluidic environment
Research Projects (ERDF)

- **Medipump**: Microsystem for controlling a medical perfusion pump
- **Monsotex**: Integration of sensors in a textile (smart clothes) for medical applications
- **Remanos**: Autonomous microsystems for industrial applications (energy harvesting and power management)
- **Minatis**: Packaging of dies made by UCL
- **Tracemedia**: Packaging of microsystem for track and trace.
Projets Piµi et Piµi-2

www.plushaut.be
Piµi platform

- Piµi: Platform for the integration of industrialisable microsystem

- Partners within the Piµi platform:
  - www.microsys.ulg.ac.be
  - www.cewac.be
  - www.centexbel.be
  - www.sirris.be
  - www.umons.ac.be
  - www.materianova.be
• Conception and realization of smart textile for sleep monitoring

ECG with fully textile ECG electrodes and distributed electronic using flexible electronic

Prototype of fully integrated textile shirt for apnea monitoring
• A new kind of medical perfusion pump, fully controlled with disposable sensors, for very small flow. Pressure sensors, flow sensors, bubble sensors.
• Development of an integration platform for autonomous microsystems
• Integration of unconventional substrates, non-planar, autonomous microsystems (for energy recovery and storage management, communication) and specific cases
• Identifying industrial needs and building capacity of support for applied research

$e = 150 \mu m$
Bio-sensor for protein detection (DNASip project): Bio chip and Microfluidic device integrated in one fully functional device
Principe of detection

The inter-digitated array microelectrodes (IDAM) is covered with a bio-functional layer (specific antibody recognizing the nucleoprotein of the Influenza A virus). The registered response is variation of the capacitance and conductivity between the IDAM. To increase the signal a 40 nm gold nano-bead are conjugated with influenza A virus.
Si sensor die of 3.2mmx3.2mm with 4 of 200µmx200µm sensing areas (C1...C4) of different configuration IDAM (inter-digitated array microelectrodes)
Sensor die cross sectional view

Al=800nm
SiO2=50nm
Si wafer=600µm
Al=400nm
Bio-functionalization

1. Plasma/O₂ treatment
2. Silanisation
3. Coupling agent
4. Antibody
Sensing channel (configuration of 1mm width x 3 mm length and 0.5 mm high) is to doze 1-1.5 ml volume of the test sample.
Assembly process flow

• Die attach (mounting the sensor die in the package)
• Wire bonding (electrical connection between the sensor die and the package)
• Encapsulation:
  – Protect the bond pad on the sensor die
  – Protect the wire
  – Protect the lead (bond pad) on the package
  – Define the sensing area
Assembly process challenges

• Die attach:
  – Die pick and place normally required a direct top contact on the die
  – Permanent die fixation usually performed at elevated temperature (>40°C, typically 150°C)

• Wire bonding: standard technology requires elevated temperature (>40°C, typically 150°C)

• Encapsulation: standard technology requires elevated temperature (>40°C, typically 150°C)
Die mounting

• Pick and place without direct contact with sensing area (no damage to the bio-functionalized layer, no damage to vulnerable IDAM)
• Permanent fixation is achieved at room temperature
Sensing area observation

As received

After encapsulation

No visual damage induced during the assembly flow
Wire bonding

• Industrial standard is Au wire bonding. Cu wire bonding emerges. It total they counts for 90%. They requires elevated temperature (typically 150-220°C)

• We interconnect the sensor die using Al wire bonding (room temperature process)

• Al wire bonding is currently used for special application (military, space etc)
Process flow

"As received sensor die (after bio-functionalization)"

Sensor die mounted into package and wire bonded

Encapsulated sensor die (transparent encapsulant)
Assembled sensor

Cross sectional view

Selective encapsulation

Sensing area (C1…C4)

wire

die

package
Encapsulation challenges

- Partial encapsulation to define accurately the sensing area (1mm x 3 mm and 0.5 mm high):
  - dam (high viscosity) and encapsulant (lower viscosity)
  - Industrial process: partial molding

- UV curable encapsulant (UV spot intensity: 18.5W/cm² irradiance maximum output, wave length of 320-500nm), maximum 20 sec

- Such UV exposure causing no direct damage to bio-functionalized layer of the sensor (tested experimentally)
Assembled sensor (top view)
Electrical characterization

- Capacitance and conductivity measurements (PO$_4$ buffer; 20 mM, pH 8)(freq=100 kHz): the measurements were performed with a LCR meter with different bias voltages. Different dilutions of (left) antibody conjugated with gold bead, in contact with antibodies (initial concentration= $10^{13}$ beads/mL) or (right) different dilutions of the Influenza A virus were tested.

- For the measurements of the Influenza A virus, the signal was enhanced with an anti-Influenza antibody conjugated with a gold nano-bead. The same trend was observed for both targets.
Capacitance

Ab-Au: antibody conjugated with gold nano-bead
InfA+Cau: Influenza A virus enhanced with an anti-Influenza antibody conjugated with a gold nano-bead
Conductivity

Ab-Au: antibody conjugated with gold nano-bead
InfA+Cau: Influenza A virus enhanced with an anti-Influenza antibody conjugated with a gold nano-bead
Conclusion

- We developed a convenient method for the assembly of the bio-functionalized sensor
- The process temperature is below 37°C; there is no direct contact between the die handling tool and the bio-functionalized area of the bio-sensor
- Additionally, the UV exposure, specifically intensity and time are limited to a sustainable level for inducing no damage to the bio-sensor
- The realized sensor performs detection and semi-quantification of influenza A viruses.
Partner and contact

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