INTEGRAM*plus*

Integrated MNT Platforms and Services

Europractice Service Project providing Development Platforms for Integrated Micro-Nano Technologies and Products

Carmen Moldovan, Bogdan Firtat
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INTEGRAM*plus* - Integrated MNT Platforms and Services

Aim: Highly integrated microsystems combining smart Si functionality with polymer platforms in a multi-domain environment

- Address and stimulate future market needs via higher levels of integration in stable, manufacturable MNT processes enabling nano via micro
  - **Emerging markets**: biomedical & healthcare; pollution & security; comms (RF & optical)
  - **Multi-domain integration**: bio-optical-fluidics, MEMS and/or electronics; mixed process technologies (silicon-polymer)
- Stimulate take up of smart (integrated) MNT products
- Reduce barriers to MNT access
  - training and standardisation
  - provide development platforms and standard modules
- Provide low cost MNT prototyping services
  - enable virtual manufacturing based on Design for Manufacture principles
  - Silicon MEMS and polymer prototyping
- Provide seamless service across the MNT supply chain
  - from concept to production
  - 10 partners from 7 countries + extended supply chain network

Laboratory of Microsystems for Environmental and Biomedical Applications

Carmen Moldovan – Head of Laboratory for Environmental and Biomedical Applications –15 years of experience in MEMS technologies

- Associate professor
- Coordinator and partners of more of 25 national projects and 10 EU projects
- Former NEXUS Steering Committee member
- ISTAG group member within DG - INFSO, EC

Bogdan Firtat – Scientific Researcher, 10 years experience in MEMS technologies: design, simulation and modelling for mechanical, chemical and biological microsensors and FEM microfluidic modelling.

PARTNERS

QinetiQ Ltd., Malvern, UK	Coventor sarl, Paris, France
CSEM, Alpnach, Switzerland	Lancaster University, UK
Epigem Ltd., Redcar, UK	National Institute for R&D in Microtechnologies, Bucharest, Romania
Institut für Mikrotechnik, Mainz, Germany	Institute of Electron Technologies, Warsaw, Poland
Silex, Sweden	Yole Développement, Lyon, France

INTEGRAM*plus* - FP6 Integrated Project

Europractice Service Project providing Development Platforms for Integrated Micro-Nano Technologies and Products

EUROPRACTICE

INTEGRAM*plus* Organisation

CAD TOOLS & VIRTUAL MANUFACTURE

IMT (Biointegration & microfluidic design) | Coventor (Multi-domain software & Design for Manufacture) | ITE (Electronics & microfluidic design)

DESIGN SERVICES, PROTOTYPING & LOW VOLUME MANUFACTURE

IMM (polymer) | CSEM (polymer, silicon) | QinetiQ (silicon) | U. Lanc. (PATENT)

VOLUME MANUFACTURE

EPIGEM (polymer manufacture) | Silex Microsystems (Silicon / glass manufacture)

CUSTOMER SUPPORT

Yole Developpement (Strategic Marketing)

SUPPLY CHAIN PARTNERS

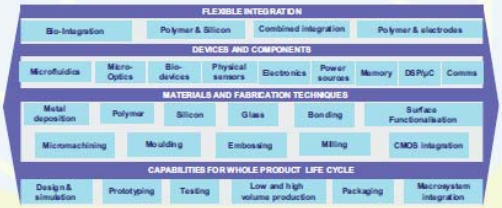
X-Fab (CMOS manufacture) | AMIS (CMOS manufacture) | MCE (packaging) | C-MAC (volume assembly) | Hymite (packaging)

DELTA (packaging) | AML (bonding) | Micronit (glass manufacture) | Expert Consultants (PATENT-DIMM members)

The INTEGRAM*plus* Partners' Technology Portfolio

European partners in micro and nanotechnologies with complementary expertise in:

- Silicon, polymer, glass, hybrid solutions
- Multi-domains (optics, fluidics, MEMS, bio, chemical, electronics)
- Multi-level integration (material, electronics, functions and system)
- Development and production along the supply chain



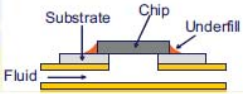
Multi-domain Integration - Technological issues

Issues being addressed

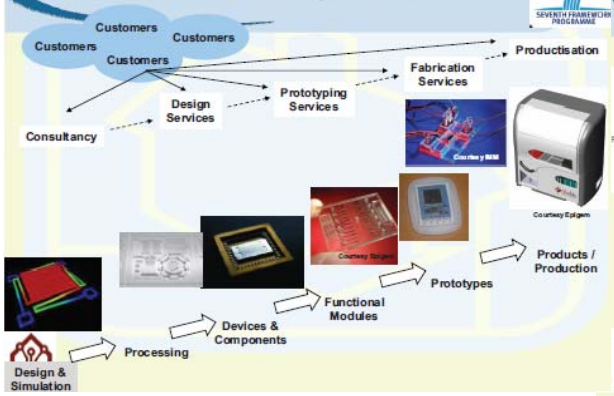
- Fabrication of chips with electrodes
- Fabrication of polymer parts with electrical leads (injection molding, lithography, ...)
- Fabrication of microstructured gaskets (casting, laser cutting, punching, ...)
- Fabrication of polymer parts (micromachining, casting, embossing, injection molding, ...)
- Electric contacts between chip and leads (flip-chip, solder bumps, wire bonding, ...)
- Hybrid bonding technologies (surface activation, thermal bonding, ...)
- Hollow waveguides (fabrication, sealing, integration)
- Adhesive bonding technologies (glues, double sided sticky tapes, ...)
- Surface functionalization (biochemistry, nanopatterning, ...)
- Connections to macro world (fluid ports & reservoirs, electrical contacts, light contacts)
- Fabrication of silicon/SOI parts (DRIE, anisotropic wet etch, chemical vapour etch, ...)
- Integration of silicon into polymer

Competencies needed

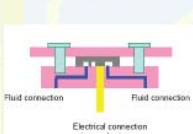
- (Si) chip fabrication
- Microchannel fabrication
- Optical components
- Surface functionalization
- Channel sealing
- Microfluidic interfacing
- Optical interfacing
- Electrical interfacing



INTEGRAM*plus* offer

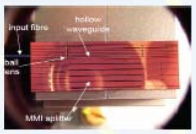


INTEGRAMplus multi-domain multi-technology platforms



Si chip scale package with polymer microfluidic chip and electrical connections

Epigem microfluidics chip with integrated electrodes and pcb headers mounted



Hollow waveguide

- Advanced optical circuit modules
- Combined fluidic and optical modules

Innovative silicon-polymer integration technology for chips onto substrates with fluid access opening using flip-chip bonding

Service Offerings

Currently 3 Prototyping Platforms:

1. QinetiQ Silicon MEMS Prototyping Service
2. Epigem Modular Microfluidic Prototyping Service
3. IMM Rapid Prototyping Service for Lab-on-a-chip

INTEGRAM*plus* Summary

- Provides industry with a world-leading facility to stimulate take-up and accelerate time-to-market of smart mixed-technology components and solutions.
  - A consortium offering tried and tested micro and nano technology expertise from10 partners operating across 7 European countries.
  - A design and prototyping service with route to volume manufacture for highly integrated microsystems.
  - High degree of flexibility to address the need for increased complexity in microsystems without sacrificing the requirement for manufacturable processes.
  - A flexible customer interactive approach ensures access to INTEGRAM*plus* at any stage in the product lifecycle.

Web-sites:	www.integramplus.com www.QinetiQ.com/mems
Email:	info@integramplus.com
Tel:	+44(0)1684896262

Mission and main activities

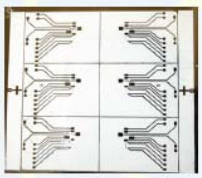
The Laboratory of Microsystems for Biomedical Applications is doing **research**, focused on development of microsensors and sensors integration such as:
- **chemosensors** (O_2, pH, NO_2, NOx, CO, CO_2, humidity etc.);
- **biosensors** (enzymatic, immunosensors, biomicrosensors array);
- **nanowire based ISFET**
- **microprobes** for recording of electrical activity of cells and tissues,
- **microfluidic platforms**,
- **signal processing and data acquisition for** microsensors array, technologies for sensor integration, data processing, transmission and acquisition.

The Lab is running **services for industry** in design, simulation, technology, testing and data acquisition, processing and transmission **and education** in the field of mixed technologies.

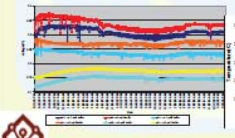
The Laboratory was involved in several FP6 projects in the area of technologies for sensors integration, microfluidics and software and hardware development for data acquisition.
IMT's tasks in the project are: simulation and modelling of fluidics and temperature distribution inside the microsystem channels, and computational modelling of the integrated multi-sensing system. Also IMT will be developing the auxiliary sensors for monitoring the cell culture's environment and will work on microfluidic microsystem integration.

Resources: The Laboratory has 11 permanent researchers and 2 part time co-workers from a total of 170 employees (researchers and administration).

Sensors on glass and platform

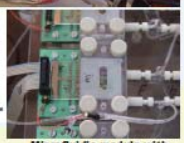


Platform



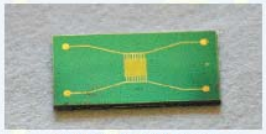
pH sensor

Temperature sensor

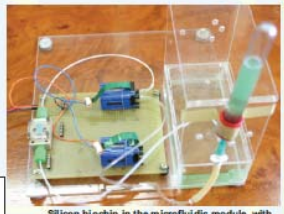


Microfluidic module with the reference electrode

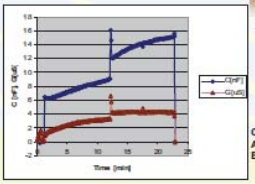
Sensors technology



Gold electrodes pesticide sensor



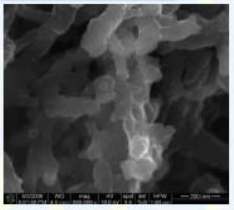
Silicon biochip in the microfluidic module, with pumps and reservoir



Conductance and capacitance:
A – substrate injection,
B – inhibitor injection

Auxiliary sensor - pH sensor nanofiber polyaniline based

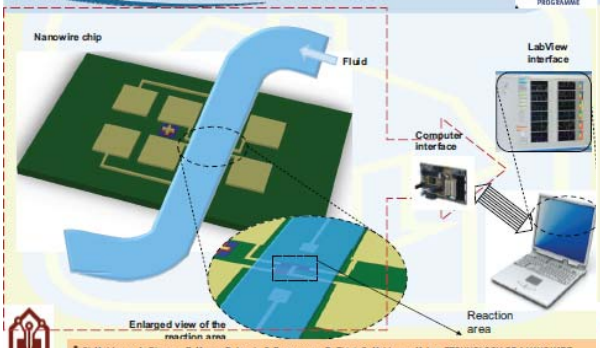
- The **pH sensor** is a solid state sensor based on conductive polymers, miniaturized, developed on silicon substrate
- The sensor measurement is a voltage measurement at zero current. The voltage is measured between two electrodes: the active electrode and the reference electrode (Ag/AgCl, KCl 3M).
- The gold electrode was deposited with a layer of polyaniline conductive emeraldine base form as seen in the SEM.
- The electrochemical deposited polyaniline has an intrinsic nanowires structure of 100nm diameter



SEM picture of electrochemical deposited polyaniline conductive layer in the form of nanofibers

Carmen Moldovan, Rodica Iosub, Radu Cornel, Eric Moore, Anna Paschero, Walter Messina, Danilo Demarchi, Cecilia Codreanu, Daniel Necula, Adrian Dinescu, Bogdan Firtat, **Sensor system for on-line monitoring of cell cultures**, CAS'09 (International Conference on Semiconductors), IEEE catalog Number CFP09CAS-PRT, **ISBN: 978-1-424-4412-7**; pp 263-267

NW ISFET sensor



* Cl. Moldovan, A. Dinescu, E. Manea, R. Iosub, C. Brasoveanu, B. Firtat, C. Moldovan, M. Ion, *TECHNOLOGY OF A NANOWIRE BIOFET DEVICE FOR BIOMOLECULES DETECTION* , CAS 2009 Proceedings; ISBN: 978-1-4244-4413-7, Vol.2, pag.549-552

Integration

Connections, signal processing, data acquisition, GUI

Labview interface

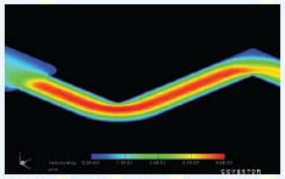
Automatic measuring set-up

The graphic user interface designed with the LabView. By the program we can control: Acquisition time, Number of loops, Time between the loops, Flow rate in the channels

Integration

Microfluidics

Microfluidic set-up



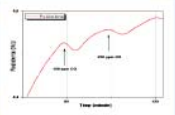
Visual results of the continuous flow simulation (section through the z plane) – detail

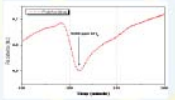
The velocity of the fluid into the channel simulation has been performed***

*****B. Firtat, C. Moldovan, G. Boldeiu,** *FEM Microfluidic simulations for microchannels – continuous and droplet-like flow; The 4M/ICOMM Conference, 23-25 Sept. 2009, Karlsruhe, Germany; Proceedings, pp 205*

New developments

Flexible substrate – gas sensors, batteries





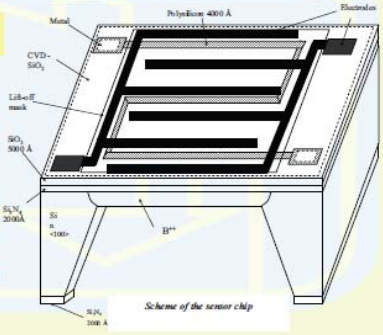
CO_2 GAS SENSORS

Membrane suporting sensor

High dose boron is implanted and diffused followed by a boron doping from solid source + diffusion (1050°C, 4 hours). ➔ the p-n junction, 12 µm depth, for anisotropical stop etch

A CVD oxide is deposed such as dielectric layer and the contacts on polysilicon layer are open

Cr-Au deposition and configuration follow.

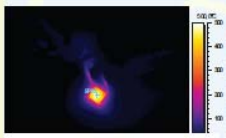


Scheme of the sensor chip

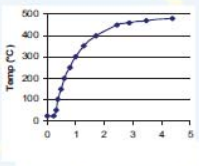
New developments

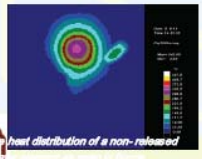
- Ink Jet Technology – sensors on paper for gases detection
- Integration: signal processing, GUI

Ceramic gas sensor – integrated heater



The input power was 1,1 W and this should be compared with the non-released heater element that requires 2,4 W input power of to reach 490 °C





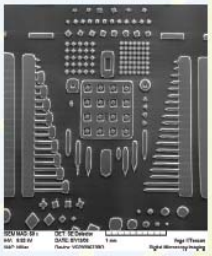
heat distribution of a non- released

Modelling and simulation activities

Design for Manufacture (etch simulations)

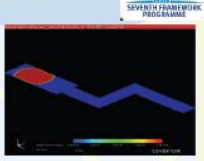
Calibration of a new software application (Etch3D – developed by Coventor, Inc.), designed for anisotropic silicon etching simulations.

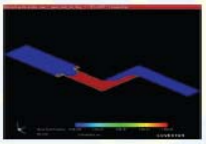
- test structures were used, with different sizes and shapes;
- the real test structures (etched in both KOH and TMAH, with different temperatures, concentrations and etch times) were compared to the simulation results;
- the program's internal parameters were adjusted, in order to fit the lab results.

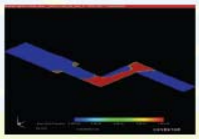


Microfluidic modelling

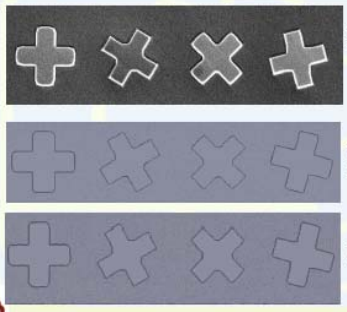
- Dead volume and cross contamination
  - Model compatibility issues solved for different platforms
  - Several simulations performed:
    - Continuous flow analysis (velocity, pressure, etc.);
    - Slug-flow analysis (fluid bubbles through channels);
    - Identification of fluids cross-contamination and dead-volumes.







Design for Manufacture (etch simulations)



SEM picture of the etched test structure (TMAH, 25%, 80° C, 5 min.)

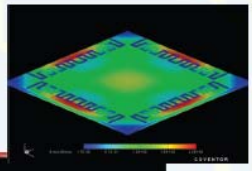
Simulation using default values of the program parameters (for TMAH, 25%, 80° C, 5 min.)

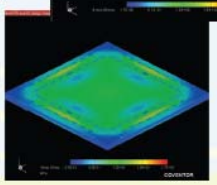
Tuned values of the program parameters (TMAH, 25%, 80° C, 5 min.).

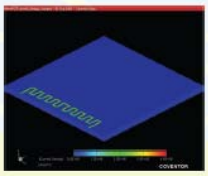
Experimental and simulation results for the 4-crosses test structure (using TMAH)

Multi-domain modelling

- Modelling of a thin membrane silicon pressure sensor
  - Micro-mechanical simulation (membrane deflection, stress induced);
  - Electrical and piezoresistive simulation (for determining the current change due to the mechanical stress induced by the applied pressure).

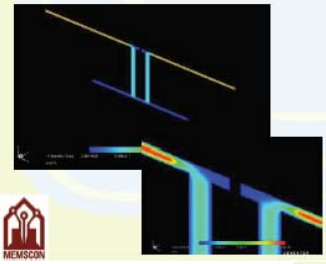


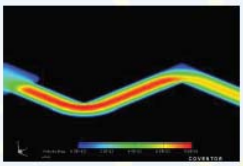




Microfluidic modelling

- Microfluidic simulations were performed, in order to analyse one fluid velocity through a specific microchannel design. The simulations were used to observe the flow speed and direction of the liquid passing through, and also dead spots in the flow (zones with much slower velocity), for different fluid flow rates.





Conclusions

- Continuing technology development
- New technologies for platforms develop
- Offering services: sensors and platform prototyping, simulation, training

Interest:

- New projects partnership
- Industry attracting, bringing inventions to innovations
- Start-up development

THANK YOU!

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